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Advancement of Science

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REPORT

OF THE

THIRTY-SECOND MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT CAMBRIDGE IN OCTOBER 1862.

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OBJECTS AND RULES

OF

THE ASSOCIATION.

UNIVERSITY
CALIFORNIA

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The Association contemplates no interference with the ground occupied by other institutions. Its objects are,—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another, and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

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All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

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Annual Subscribers shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this Subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis*: but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

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2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.

3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]

4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]

5. Associates for the year, subject to the payment of One Pound.

6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members who have not intermitted their Annual Subscription.

2. *At reduced or Members' Prices*, viz. two-thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]

3. Members may purchase (for the purpose of completing their sets) any of the first seventeen volumes of Transactions of the Association, *and of which more than* 100 *copies remain*, at one-third of the Publication Price. Application to be made (by letter) to Messrs. Taylor & Francis, Red Lion Court, Fleet St., London.

Subscriptions shall be received by the Treasurer or Secretaries.

MEETINGS.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee at the previous Meeting; and the Arrangements for it shall be entrusted to the Officers of the Association.

GENERAL COMMITTEE.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

1. Presidents and Officers for the present and preceding years, with authors of Reports in the Transactions of the Association.

2. Members who have communicated any Paper to a Philosophical Society, which has been printed in its Transactions, and which relates to such subjects as are taken into consideration at the Sectional Meetings of the Association.

3. Office-bearers for the time being, or Delegates, altogether not exceeding three in number, from any Philosophical Society publishing Transactions.

4. Office-bearers for the time being, or Delegates, not exceeding three, from Philosophical Institutions established in the place of Meeting, or in any place where the Association has formerly met.

5. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing for the Meeting of the year by the President and General Secretaries.

6. The Presidents, Vice-Presidents, and Secretaries of the Sections are *ex-officio* members of the General Committee for the time being.

SECTIONAL COMMITTEES.

The General Committee shall appoint, at each Meeting, Committees, consisting severally of the Members most conversant with the several branches of Science, to advise together for the advancement thereof.

The Committees shall report what subjects of investigation they would particularly recommend to be prosecuted during the ensuing year, and brought under consideration at the next Meeting.

The Committees shall recommend Reports on the state and progress of particular Sciences, to be drawn up from time to time by competent persons, for the information of the Annual Meetings.

COMMITTEE OF RECOMMENDATIONS.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects, shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee, unless previously recommended by the Committee of Recommendations.

LOCAL COMMITTEES.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

OFFICERS.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer, shall be annually appointed by the General Committee.

COUNCIL.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

PAPERS AND COMMUNICATIONS.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

ACCOUNTS.

The Accounts of the Association shall be audited annually, by Auditors appointed by the Meeting.

I. Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. York, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. Oxford, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. Cambridge, June 25, 1833.	G. B. Airy, F.R.S., Astronomer Royal, &c. John Dalton, D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. Edinburgh, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. Dublin, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. Bristol, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London Liverpool, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. Newcastle-on-Tyne, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, F.L.S., &c. Wm. Hutton, F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. Birmingham, August 26, 1839.	Marquis of Northampton. Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. Glasgow, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount Edgecumbe.	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. Plymouth, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir D. T. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. Manchester, June 23, 1842.	John Dalton, D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, M.D. James Heywood, Esq., F.R.S.

The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	Earl of Listowel. Viscount Adare Sir W. R. Hamilton, Pres.R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. Professor Powell, F.R.S.	Henry Clark, M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. DelaBeche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's.	Matthew Moggridge, Esq. D. Nicol, M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews. EDINBURGH, July 21, 1850.	Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S.L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, M.R.I.A., Pres. R.S. Sir Henry T. DelaBeche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., & Pres. Camb. Phil. Society HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Philos. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, M.D., V.P. Hull. Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S.L. & E., F.R.A.S. Joseph Brooks Yates, F.S.A., F.R.G.S.	Joseph Dickinson, M.D., F.R.S. Thomas Inman, M.D.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugall, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Honourable the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, LL.D.

RICHARD OWEN, M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.I.C.E. Joseph Whitworth, Esq., F.R.S., M.I.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, M.A., Esq. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq. Isaac Lowthian Bell, Esq. Nicholas Wood, Esq. Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE GENERAL TREASURER'S ACCOUNT from 4th September 1861 (commencement of MANCHESTER MEETING) to 1st October 1862 (at CAMBRIDGE).

RECEIPTS.

	£	s.	d.
To Balance brought on from last Account	244	13	3
Received Life Compositions at Manchester Meeting and since	1209	0	0
" Annual Subscriptions, ditto ditto	543	0	6
" Associates' Tickets, ditto ditto	1589	0	0
" Ladies' Tickets, ditto ditto	791	0	0
" Dividend on Stock, 12 Months	216	11	3
" from the Sale of Publications—viz., Reports, Catalogues of Stars, &c.	124	6	7
" Book Compositions	5	0	0
	£4722	11	7

Examined and found correct.

J. P. GASSIOT,
R. HUTTON,
NORTON SHAW, } *Auditors.*

PAYMENTS.

	£	s.	d.	£	s.	d.
By paid Expenses of Manchester Meeting, Sundry Printing, Binding, Advertising, and Incidental Petty Payments by the General Treasurer and the Local Treasurers				462	0	2
Paid on account of Printing Report of 29th Meeting (balance)				228	18	9
Do. Printing and Engraving 30th Meeting (in part)				504	13	5
Purchase of £1500 3 per cent. Consols				1388	15	0
Salaries, 12 months				450	0	0
On account of Grants made at Manchester Meeting, viz.—						
For Maintaining Establishment of Kew Observatory	£500	0	0			
Patent Laws	21	6	0			
Mollusca of N.-W. America	10	0	0			
Natural History by Mercantile Marine	5	0	0			
Tidal Observations	25	0	0			
Photo-heliometer at Kew	40	0	0			
Photographic Pictures of the Sun	150	0	0			
Rocks of Donegal	25	0	0			
Dredging Durham and Northumberland	25	0	0			
Connexion of Storms	20	0	0			
Dredging N.-East Coast of Scotland	6	9	6			
Ravages of Teredo	3	11	0			
Standards of Electrical Resistance	50	0	0			
Railway Accidents	10	0	0			
Balloon Committee	200	0	0			
Dredging Dublin Bay	10	0	0			
Dredging the Mersey	5	0	0			
Prison Diet	20	0	0			
Gauging of Water	12	10	0			
Steamships' Performance	150	0	0			
Thermo-Electric Currents	5	0	0			
				1293	16	6
Balance at Bankers	£392	3	2			
Ditto in General Treasurer and Local Treasurers' hands	2	4	7			
				394	7	9
				£4722	11	7

II. Table showing the Names of Members of the British Association who have served on the Council in former years.

Aberdeen, Earl of, LL.D., K.G., K.T., F.R.S. (deceased).
Acland, Sir Thomas D., Bart., M.A., D.C.L., F.R.S.
Acland, Professor H. W., M.D., F.R.S.
Adams, Prof. J. Couch, M.A., D.C.L., F.R.S.
Adamson, John, Esq., F.L.S.
Ainslie, Rev. Gilbert, D.D., Master of Pembroke Hall, Cambridge.
Airy, G. B., M.A., D.C.L., F.R.S., Astronomer Royal.
Alison, Professor W. P., M.D., F.R.S.E. (dec^{d}).
Allen, W. J. C., Esq.
Anderson, Prof. Thomas, M.D.
Ansted, Professor D. T., M.A., F.R.S.
Argyll, George Douglas, Duke of, F.R.S. L. & E.
Arnott, Neil, M.D., F.R.S.
Ashburton, William Bingham, Lord, D.C.L.
Atkinson, Rt. Hon. R., Lord Mayor of Dublin.
Babbage, Charles, Esq., M.A., F.R.S.
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Report of the Council of the British Association, presented to the General Committee, Wednesday, October 1, 1862.

1. The Council were directed by the General Committee at Manchester to maintain the Establishment of the Kew Observatory, and a grant of £500 was placed at their disposal for the purpose. They have received at each of their Meetings regular accounts of the proceedings of the Committee of the Observatory, and they now lay before the General Committee a General Report of these proceedings during the year 1861–62. (See Report of Kew Committee for 1861–62.)

2. A sum of £40 was placed at the disposal of the Kew Committee for the employment of the Photoheliometer; and a further sum of £150 for the purpose of obtaining a series of photographic pictures of the Solar surface, with the cooperation of the Royal Society. The Report of the Kew Committee will make known the results of these recommendations.

3. The Report of the Parliamentary Committee has been received by the Council for presentation to the General Committee today, and is printed for the information of the Members. (See Report of Parliamentary Committee.)

4. The Council have to regret the absence from this Meeting of the General Secretary, Mr. Hopkins, through indisposition, which they sincerely hope will soon be removed.

5. The 'Classified Index' to the Transactions of the Association, which was authorized to be prepared under the direction of Professor Phillips, is completed in one of the main divisions; the remainder will be printed without delay, and will be delivered to the Members who have subscribed for it before the end of the present year.

6. At that date it is the request of Professor Phillips to be allowed to withdraw from the office of Assistant General Secretary to which he has been appointed, by Annual Election in the General Committee, for nearly thirty-two years. Having for two years received the useful aid of Mr. G. Griffith, M.A., of Jesus College, Oxford, he has expressed to the Council his conviction of the fitness of that gentleman to undertake the duties which have been so long entrusted to himself.

7. The Council having considered the subject, and having ascertained from Professor Phillips that he would be happy to cooperate with Mr. Hopkins as Junior General Secretary in the next year, recommend that the arrangement here suggested be carried out by the General Committee.

8. The Council received in April, 1862, a communication from Mr. John Taylor, Jun., and Mr. Richard Taylor, requesting that, on account of his great age, their father, Mr. Taylor, might be relieved of all further duties as General Treasurer and Co-Trustee of the Association.

The warmest thanks of the Council were given to Mr. Taylor for his kind attention and most valuable services rendered to the Association in two important offices, as one of the Trustees and sole General Treasurer, and their regret that any cause should render it necessary for him to desire to be relieved from the duties which he has so efficiently performed for the great advantage of the Association, almost from its foundation.

9. Sir Philip de Grey Egerton, Bart., was then requested to accept the office of Trustee of the British Association; and Mr. W. Spottiswoode to undertake the duty of General Treasurer to the Association.

These Gentlemen have kindly consented to act, and have entered on their duties.

10. The Council have been informed that Invitations will be presented to

the General Committee at its Meeting on Monday, October 6, from Newcastle-on-Tyne, Birmingham, Bath, Nottingham, and Dundee.

11. That the Vice-Chancellor of the University of Cambridge and the Rev. Professor Challis be elected Vice-Presidents for the next year.

October 1, 1862.

William Fairbairn,
President.

Report of the Kew Committee of the British Association for the Advancement of Science for 1861–1862.

The Committee of the Kew Observatory submit to the Association the following Report of their proceedings during the past year.

Deeming it desirable that the instrumental arrangements and scientific processes at use in the Observatory should be represented at the International Exhibition, application was made to the Commissioners for space.

This was granted in the nave of the building, where the following instruments are at present exhibited:—

1. A set of Self-recording Magnetographs.
2. An instrument for tabulating from the traces furnished by the Magnetographs.
3. A Unifilar.
4. A Dip Circle.
5. A Self-recording Anemometer.
6. Barometers.
7. An instrument for testing Thermometers, also a Kew Standard Thermometer.
8. Sun Pictures, taken by the Kew Heliograph.

The Committee have the pleasure to inform the Association that a Medal has been awarded to the Kew Observatory for excellence and accuracy of construction of instruments for observing terrestrial magnetism; and that two Medals have likewise been awarded to Mr. R. Beckley, Mechanical Assistant at Kew, for his Registering Anemometer, and for his Photographs of the Sun.

It is proposed that application be made to the Government Grant Committee of the Royal Society for the expenses incurred through this exhibition.

At the time when the last Report was made to the Association, the Staff at Kew were occupied with the verification of a set of magnetic instruments belonging to Prof. De Souza, of the University of Coimbra, a gentleman who was present at the Meeting at Manchester. The examination of these was shortly after completed, and the instruments, consisting of a set of Self-recording Magnetographs, a tabulating instrument, a Dip Circle, and a Unifilar, have since been safely received at Coimbra.

The following letter was addressed to the Chairman by Prof. De Souza shortly before his departure:—

"London, 26th October, 1861.

"My dear Sir,—I cannot leave England, where I have been exceedingly favoured by the Committee of the Kew Observatory of the British Association, without expressing to you my hearty thanks for the help I have experienced from the Committee in the construction and verification of the Magnetic and Meteorologic instruments for the University of Coimbra, as well as for the valuable instruction which I have received, guided by the Director of the Kew Observatory, and the kindness which the British Association has shown me in their magnificent Meeting. I shall never forget the help afforded to me in so many different ways, and I desire earnestly to put it in immediate contribution towards *the advancement of science*.

"The Observatory of Coimbra must have in its library, as a memorial, the valuable collection of Transactions of the British Association, and I hope that you may be so kind as to put me in the way of obtaining these volumes.

"I remain, dear Sir,
"Sincerely yours,
"*J. P. Gassiot, Esq.*" "JACINTHO A. DE SOUZA."

The request of this letter has been complied with by the Council of the Association, and a complete set of the Transactions has been dispatched to Coimbra.

The Director of the Lisbon Observatory has since requested the Committee to superintend the construction of a set of self-recording Magnetographs. The Committee, in complying with his request, have made arrangements for the instruments at present exhibited in the International Exhibition, and these will afterwards be mounted at the Kew Observatory for inspection and verification.

A Differential Declinometer for the Government Observatory at Mauritius has been verified and forwarded to Prof. Meldrum, who has received it in safety.

Lieut. Rokeby, of the Royal Marines, already favourably known by a meteorological register very carefully kept at Canton during its occupation by the British troops, has received instruction at Kew in the use of magnetical instruments, and has been furnished with a Dip Circle, a Unifilar, a Bifilar, and a Differential Declinometer, of which the constants have been determined at the Observatory. Lieut. Rokeby proposes to employ these instruments at the Island of Ascension during his term of service at that station. He has also been furnished by Admiral FitzRoy with a complete equipment of the meteorological instruments supplied by the Board of Trade. The importance of Ascension as a magnetical station has long been recognized. Situated very nearly on the line of no magnetic dip, the determination of the periodical variations and of the secular changes of the three magnetic elements cannot fail to possess a high value; and as a meteorological station, a rock in the mid-ocean, within 6° of the Equator, presents an almost unrivalled locality for an exact measure of the amount of the lunar atmospheric tide, and of the variations in direction and force of the trade-wind. The Admiralty, apprised of Lieut. Rokeby's meritorious purposes, have sanctioned the appropriation of the officers' quarter at the summit of the Green Mountain, known as the "Mountain House," as an observatory; and the department of the Board of Trade, under Admiral FitzRoy's superintendence, has authorized the expenditure of £50 in providing the additional accommodation required for the instruments. Lieut. Rokeby has arrived at Ascension with the instruments uninjured, and writes in strong terms of the support he receives from Captain Barnard, the commander of the troops on the island.

On June 19th the Chairman received a letter from the Astronomer Royal, in which he stated that he was very desirous of comparing the Greenwich records of the vertical-force magnet with those at Kew; and that, if agreeable to the Committee, he would request Mr. Glaisher to endeavour to arrange a meeting with Mr. Stewart for that purpose.

The Chairman immediately replied, offering every facility, and Mr. Glaisher has since visited the Observatory, where the comparison has been made.

The usual monthly absolute determinations of the magnetic elements continue to be made, and the self-recording magnetographs are in constant operation under the zealous superintendence of Mr. Chambers, the Magnetical Assistant.

Major-General Sabine, Pres. R.S., has laid before the Royal Society a paper entitled "Notice of some conclusions derived from the Photographic Records of the Kew Declinometer in the years 1858, 1859, 1860, and 1861."

The exceedingly good definition which the labours of the late Mr. Welsh procured for the magnetic curves, has also enabled the Superintendent, Mr. Stewart, to discuss the disturbance-curves by a peculiar method, depending on such definition; and he has presented a paper to the Royal Society "On the forces which are concerned in producing the larger magnetic disturbances."

The Committee are at present engaged in investigating the best means of multiplying copies of these curves, and exhibit to the Association two prints from such—one kindly taken by Sir Henry James by his process, and the other taken by that of Mr. Paul Pretsch.

The expense incurred by Mr. Pretsch has been defrayed by £25 obtained from the Government Grant through the Royal Society.

The Chairman of the Balloon Committee having applied to the Superintendent for the instruments used by the late Mr. Welsh in his ascents, these were delivered over to Mr. Criswick on the 12th of March last, having been previously verified at the Observatory.

The Meteorological work of the Observatory continues to be performed in a satisfactory manner by Mr. George Whipple, and each Member of the Staff of the Observatory seems much interested in the duties he is called upon to discharge.

During the past year 184 Barometers and 282 Thermometers have been verified; and, to give an idea of the amount of this kind of work which has been accomplished since first the subject was commenced in the year 1854, it may be stated that no fewer than 1185 Barometers and 6429 Thermometers have been verified up to this date.

Rear-Admiral FitzRoy having been informed of the existence at the Observatory of a Barograph invented and used by Mr. Ronalds, the following letter was addressed by him to the Chairman:—

(*Copy.*)

"Board of Trade (and Admiralty) Meteorological Department,
2 Parliament Street, London, S.W., 7th April, 1862.

"SIR,—I have the honour to address you as Chairman of the Kew Committee of the British Association for the Advancement of Science, on behalf of this branch department of the Board of Trade and the Admiralty.

"I am authorized to request that you will allow us to endeavour to benefit by your regular photographic self-registration of the Barometer at the Kew Meteorological and Magnetical Observatory during at least one complete year of continuous record, by causing this office to be furnished with copies of photographic tracings, or their results, in *full detail*.

"The objects specially in view here, are:—

"Such accurate and indisputable continuous delineation of atmospheric pressure, or (rather) tension, as can only be obtained by perfectly reliable means; and

"Such details of *occasional* oscillations, or pulsations (so to speak), as can best be obtained photographically.

"For practical daily purposes, a self-registering Barometer, on the Milne principle, may be sufficient; but for elaborate analysis of atmospherical conditions and changes, in connexion with the numerous influences operating, some occasionally, some frequently, others *always*, in the air and its ever-restless currents, such an apparatus as that now available at Kew would appear to be indispensable.

"Besides ordinary meteorological peculiarities, the direction of magnetic earth-currents, the occurrence of magnetic storms, the differing electrical conditions of various currents of air, the phenomena of earthquakes, and their 'lightnings'*, seem to be more or less in certain relations to atmospheric tension, and therefore to require a close and unbroken barometrical registration. Towards some additional expense incurred by the Kew Observatory in complying with this request, I am authorized to say that this department will contribute, on principle similar to that of verification of instruments.

"I have the honour to be,
"Sir,
"Your obedient Servant,
(Signed) "ROBERT FITZROY, *R. Adm.*"

"P.S. Probably *two* scales of tracing, analogous to 'Sailing Charts' and 'Particular Plans,' would be convenient."

"*John Peter Gassiot, Esq., F.R.S.,*
Chairman of the Kew Committee of the
British Association."

To which the Chairman shortly afterwards replied in the following terms:—

(*Copy.*)

"Kew Observatory, 23rd April, 1862.

"SIR,—I have the honour to acknowledge receipt of your letter of 7th inst., addressed to me as Chairman of the Kew Committee of the British Association.

"On behalf of this Committee, I may state in reply that it will afford us much satisfaction to furnish your department with Photographic Self-registrations of the state of the Barometer at Kew Observatory.

"I am informed by Mr. Stewart, our Superintendent, that we have in our possession an instrument well calculated, with some slight alterations, to produce the results you desire.

"It possesses a compensation for temperature; besides which, it will be placed, when finally in action, in a room where the daily range of temperature is not more than half a degree Fahrenheit.

"This instrument is not yet, however, in working order, and two months may perhaps elapse before it is quite ready. As you seem to think it desirable to obtain occasionally curves on an enlarged scale, it will be matter for our consideration whether this can be managed, and how. You will be duly informed of our resolution; but, in the mean time, I may state that it would be somewhat more than two months before such additional curves could be ready. In conclusion, without binding ourselves to any specified time (which, indeed, would not be desirable in a matter of this nature), I beg to assure you that we shall do all in our power to hasten the desired result; and, as we hope to have things ready in the course of two or three months, we shall then also be prepared to reply to you with respect to remuneration for the additional work which the Observatory would thus undertake.

---

* Secchi and Palmieri, 1862.

"I have the honour to be,
"Sir,
"Your obedient Servant,
(Signed) "J. P. GASSIOT."

"*Rear-Admiral FitzRoy, F.R.S., &c.*"

The Mechanical Assistant being engaged at the Exhibition, it was found impossible to complete the alterations alluded to quite so soon as anticipated; but a curve was procured about the middle of August, which was sent to Admiral FitzRoy, and approved of by him.

The Barograph has since received some further alterations, with a view to increase its stability and general efficiency. These are now completed, and the instrument will be henceforth kept in constant operation. One of the curves from this instrument is presented to the Association.

Arrangements were made for recording photographically, by means of the Heliograph, the transit of Mercury which took place on the 12th of November last, but the weather proved unfavourable. This instrument was also in readiness for the partial eclipse of the sun which took place on the 31st of December last; but, owing to the unfavourable state of the sky, only two imperfect pictures were obtained. A very good series of sun-pictures was obtained by Mr. Beckley during the months of November and December.

The Heliograph was sent from Kew at the beginning of January to Mr. De la Rue's Observatory, and Mr. Beckley attended at Cranford to assist in erecting and adjusting it to focus; but the weather was so unfavourable during the remainder of that month that no pictures of the sun could be obtained. It had somewhat improved about the 7th of February, when the first photograph was taken, and since then others have been obtained by Mr. Reynolds (Mr. De la Rue's assistant) on every day on which this has been possible. Altogether, up to the 12th of September inclusive, 177 photographs have been taken on 124 days, namely:—

In the Month of	Number of working days.	Number of photographs procured.
February	7	13
March	10	17
April	17	31
May	17	26
June	23	28
July	20	27
August	21	26
Up to September 12	9	9
	124	177

From February 7th to September 12th inclusive there are 218 days; so that on the average one photograph was procured for 1·77 day. Nearly half of the pictures have been obtained by taking advantage of breaks in the clouds, and many have been taken through haze. In several of the photographs, owing to the unpropitious state of the atmosphere, there is a want of that beauty and perfection which the Heliograph is capable of affording; but all the pictures are sufficiently perfect for measurement by means of Mr. De la Rue's Micrometer. Many of these are extremely perfect, and all would have been so had the state of the atmosphere permitted.

During the month of August Dr. Sabler, Director of the Observatory of Wilna in Russia, resided at Cranford, and received instruction in Astronomical Photography. A Photoheliograph is being constructed for him under Mr. De la Rue's superintendence by Mr. Dallmeyer, and a Micrometer by the Messrs. Simms. This Heliograph will embody all the optical and mechanical improvements suggested by the experiments with the Kew instrument; and it is expected that the Wilna apparatus will be in operation in the spring of 1863. In the event of the Kew Heliograph being worked continuously, Sir John Herschel's suggestion that daily records of the sun should be taken by means of photography will therefore be carried out both in England and Russia; if this were done in one or two other localities, a considerable amount of information would be obtained respecting physical changes continually occurring on the sun's surface.

The experience obtained during the past year has been such as to lead Mr. De la Rue to recommend that photographic records should be continued for a series of years at some public Observatory. The Committee have had in consideration whether this could be done at Kew without interfering with the other work, and have come to the conclusion that the Heliograph might be worked at an annual expense of £200, which sum would cover the cost of an additional Assistant, who might at the same time do the other photographic work of the Observatory.

The old dome formerly used for the Heliograph is so inconveniently situated as to be quite unfit for such work, and it will be necessary to make some addition to one of the present out-buildings in order to contain the instrument. The cost of this structure is estimated at £100.

The Committee strongly recommend that the General Committee of the Association take such steps as they may consider advisable for carrying this desirable object into practical effect.

The self-recording Electrometer of Prof. W. Thomson continues in constant operation.

Mr. Francis Galton having made arrangements in the Observatory Park for testing sextants, the Observatory is now prepared to receive such instruments for examination, and to issue certificates to such as may fulfil the conditions of any of the following classes:—

A. Sextants of the highest order of workmanship for lunar observations and general service, on shore as well as at sea.

B. Sextants for naval surveys and for the determination of altitudes with as much precision as is available at sea.

C. Quadrants or sextants to be used without telescopes, for the determination of altitudes with an exactness equal to the requirements of general navigation.

The charges for examination under classes A and B will be 5*s.*, under class C, 1*s.*; and the minute constant errors of instruments under class A will be determined, when desired, at an additional charge of 5*s.*

Eight sextants have been verified at Kew since the last Meeting of the British Association.

The Observatory has been honoured with a visit from the following distinguished men of science, who had visited this country in consequence of the International Exhibition:—

Professors Dove, Magnus, and Quincke, of Berlin; Professor Förchhammer, of Copenhagen; Professors Bunsen, Kirchhoff, and Eisenlohr, of Heidelberg; Professors Kraft and Pisko, of Vienna; Professor Govi, of Turin; Professor Donati, of Florence; Professor Bolzani, of Kasan; Professor Lapschine, of

Accounts of the Kew Committee of the British Association from September 4, 1861 *to October* 1, 1862.

RECEIPTS.

	£	s.	d.	£	s.	d.
Received from the General Treasurer				500	0	0
,, for the verification of Instruments—						
from the Board of Trade	18	11	0			
from the Admiralty	15	18	0			
from Opticians	29	10	0			
				63	19	0
,, for standard thermometers				5	0	0
,, for time expended by Mr. Beckley in making apparatus for which a separate grant was provided				9	0	0
Balance				182	2	6
				£760	1	6

PAYMENTS.

	£	s.	d.	£	s.	d.
Balance from last account				79	3	7
Salaries, &c.:—						
To B. Stewart, four quarters, ending 1st October, 1862	200	0	0			
Ditto, allowed for petty travelling expenses	10	0	0			
C. Chambers, four quarters, ending 6th October, 1862	100	0	0			
G. Whipple, four quarters, ending 18th September, 1862	50	0	0			
R. Beckley, 56 weeks, ending 29th September, 1862, at 40*s.*	112	0	0			
T. Baker, 56 weeks, ending 29th September, 1862, at 12*s.*	33	12	0			
				505	12	0
Apparatus, Materials, Tools, &c.				44	16	4
Ironmonger, Carpenter, and Mason				8	6	0
Printing, Stationery, Books, and Postage				30	2	9
Coals and Gas				42	13	0
House Expenses, Chandlery, &c.				17	9	11
Porterage and petty expenses	£16	2	11	20	17	11
Ditch, &c.	4	15	0			
Rent of Land to 10th October, 1862				11	0	0
				£760	1	6
Balance				182	2	6

	£	s.	d.
I have examined the above account and compared it with the vouchers presented to me. I find that the amounts expended exceed those received by the sum of	£102	18	11
To which must be added the excess of expenditure over income for the previous year, 1861, consisting of five quarters	79	3	7
Making the present balance of expenditure beyond receipts for the last two years and a quarter amount to	£182	2	6

17th September, 1862.

R. HUTTON.

Kharkof; Professors Clausius and Wartmann, of Geneva; Captain Belavenetz, Russian Navy; and Captain Skariatine, Russian Marines.

A reference to the annexed financial statement will show that, although the expenditure has exceeded the income, the Observatory has been conducted with the utmost regard to economy; and the Committee recommend that for the ensuing year a sum of £600 should be granted, which, with other amounts to be received, will, it is expected, meet the necessary requirements.

JOHN P. GASSIOT,
Chairman.

Kew Observatory,
Sept. 29th, 1862.

Report of the Parliamentary Committee to the Meeting of the British Association at Cambridge, October 1862.

The Parliamentary Committee have the honour to report as follows:—

The Bishop of Oxford, in furtherance of the resolution adopted at Liverpool in 1854, must be deemed to have vacated his seat in this Committee, but we recommend that he should be re-elected.

Your Committee have also to report that Mr. James Heywood has not found it necessary to call upon them to interfere in the matter referred to them at Manchester by the General Committee.

WROTTESLEY, *Chairman.*

Sept. 14, 1862.

RECOMMENDATIONS ADOPTED BY THE GENERAL COMMITTEE AT THE CAMBRIDGE MEETING IN OCTOBER 1862.

[When Committees are appointed, the Member first named is regarded as the Secretary of the Committee, except there be a specific nomination.]

Involving Grants of Money.

That the sum of £600 be placed at the disposal of the Council, for maintaining the Establishment of Kew Observatory.

That the sum of £100 be placed at the disposal of the Council, for the purpose of making an addition to the out-buildings at Kew Observatory, to receive the Photoheliograph, now in the hands of Mr. De la Rue.

That the cooperation of the Royal Society be requested for the purpose of completing and proving the instruments devised for obtaining Photographic registration of the physical aspect of the Sun.

That the Committee, consisting of Professor Williamson, Professor Wheatstone, Professor W. Thomson, Professor W. H. Miller, Dr. A. Matthiessen, and Mr. Fleeming Jenkin, appointed at the Manchester Meeting, be requested to continue their Report on Standards of Electrical Resistance, and to extend it to other Electrical Standards; and that Dr. Esselbach, Sir C. Bright, Professor Maxwell, Mr. C. W. Siemens, and Mr. Balfour Stewart be added to the Committee; and that the sum of £100 be placed at their disposal for the purpose.

That the Committee to report upon Standards of Electrical Resistance, be authorized to distribute gratuitously provisional Standards of Electrical Resistance, should it appear to them advantageous to do so; and that the sum of £50 be placed at their disposal for the purpose.

That as all the Balloon Observations hitherto made under the authority of the British Association (owing to unavoidable circumstances) have been confined to the autumnal period of the year, these operations should be repeated at other periods of the year, especially during the east winds of spring, with a view to test the normal character of the observations already made;

That Colonel Sykes, Professor Airy, Lord Wrottesley, Sir D. Brewster, Sir J. Herschel, Dr. Lloyd, Admiral FitzRoy, Dr. Lee, Dr. Robinson, Mr. Gassiot, Mr. Glaisher, Dr. Tyndall, Mr. Fairbairn, and Dr. W. A. Miller be a Balloon Committee; and that the sum of £200 be placed at their disposal for the purpose.

That the sum of £70 be placed at the disposal of the Balloon Committee, to meet the deficiency in the Grant of £200 made at Manchester.

That a sum not exceeding £25, the amount of expenses necessarily incurred by Mr. Glaisher in the prosecution of the Balloon experiments, be repaid to him.

That the Committee on Luminous Meteors and Aërolites, consisting of Mr. Glaisher, Mr. R. P. Greg, Mr. E. W. Brayley, and Mr. Alexander Herschel, be reappointed; and that the sum of £20 be placed at their disposal for the purpose.

That Mr. Fleeming Jenkin be requested to continue his Report on Thermo-Electrical Experiments; and that the sum of £15 (being the balance of the Grant made to him last year) be placed at his disposal for the purpose.

That the Committee, consisting of Professor Hennessy, Admiral FitzRoy, and Mr. Glaisher, be requested to continue their inquiries relative to the connexion of Vertical Movements of the Atmosphere with Storms; and that the sum of £20 be placed at their disposal for the purpose.

That Dr. Matthiessen be requested to continue his Experiments on Alloys; and that the sum of £20 be placed at his disposal for the purpose.

That Dr. A. Dupré be requested to continue his Experiments upon the action of Reagents on Carbon under Pressure; and that the sum of £10 be placed at his disposal for the purpose.

That the Balance of Grant of £8 made at the Manchester Meeting to Mr. Alphonse Gages, of Dublin, be placed at the disposal of that gentleman.

That the Committee, consisting of Mr. R. H. Scott, Sir Richard Griffith, and the Rev. Prof. Haughton, be requested to complete their Report on the Chemical and Mineralogical Composition of the Granites of Donegal and the associated Rocks; and that the sum of £5 be placed at their disposal for the purpose.

That Mr. H. C. Sorby and Mr. C. H. B. Hambly be a Committee to make Experiments on the Fusion and Slow Cooling of various Igneous Rocks; and that the sum of £30 be placed at their disposal for the purpose.

That Professor Huxley and Sir Philip de Grey Egerton be a Committee to aid Mr. Molyneux in his Researches into the Characters and Distribution of the Organic Remains of the North Staffordshire Coal-field; and that the sum of £20 be placed at their disposal for the purpose.

That Mr. Mallet be requested to conduct Experiments to ascertain the Temperatures of the Volcanic Craters of Vesuvius and of the Temperature and Issuing Velocity of the Steam evolved at the Mouths,—the Experiments, if possible, to be extended to other Volcanic Vents in the Mediterranean Basin; and that the sum of £100 be placed at his disposal for the purpose.

That a Committee, consisting of Dr. Cobbold and Mr. J. Lubbock, be requested to prosecute their Investigations respecting the Reproduction, Development, and Migration of the Entozoa; and that the sum of £25 be placed at their disposal for the purpose.

That Professor Huxley and the Rev. Mr. Macbride be a Committee to conduct Experiments on the Artificial Fecundation of the Herring; and that the sum of £20 be placed at their disposal for the purpose.

That Mr. J. Gwyn Jeffreys, Mr. Joshua Alder, the Rev. A. M. Norman, and Mr. H. T. Mennell be a Committee for exploring the Doggerbank and other portions of the Sea-coast of Durham and Northumberland by means of the Dredge; and that the sum of £25 be placed at their disposal for the purpose.

That Mr. J. Gwyn Jeffreys, Professor Allman, Mr. John Leckenby, Professor Wyville Thomson, and the Rev. Thomas Hincks be a Committee for exploring the Coasts of Shetland by means of the Dredge; and that the sum of £50 be placed at their disposal for the purpose.

That Mr. J. Gwyn Jeffreys, Professor Allman, Professor Dickie, the Rev. Dr. Gordon, and Mr. Robert Dawson be a Committee for exploring the North-east Coast of Scotland by means of the Dredge; and that the sum of £25 be placed at their disposal for the purpose.

That Mr. J. Gwyn Jeffreys, Mr. Robert M'Andrew, Mr. G. C. Hyndman, Professor Allman, Dr. Kinahan, Dr. Collingwood, Dr. Edwards, Professor Greene, Rev. Thomas Hincks, Mr. R. D. Darbishire, and Dr. E. Perceval Wright be a Committee to superintend all the Dredging Committees of the Association; and that the sum of £10 be placed at their disposal for the purpose.

That the Committee, consisting of Dr. Edward Smith and Mr. Milner, be requested to continue their inquiries on the Influence of Prison Punishment and Dietary upon the Bodily Functions of Prisoners; and that the sum of £20 be placed at their disposal for the purpose.

That Dr. Gibb be requested to inquire into the Physiological Effects of Bromide of Ammonium; and that the sum of £8 be placed at his disposal for the purpose.

That Dr. Carpenter, Professor Huxley, and Mr. Rupert Jones, assisted by Mr. Parker, be a Committee to aid in the Construction of a Series of Models showing the External and Internal Structure of the Foraminifera; and that the sum of £25 be placed at their disposal for the purpose.

That Professor Allman and Dr. E. P. Wright be a Committee to complete a Report on the Reproductive System of the Hydroida; and that the sum of £10 be placed at their disposal for the purpose.

That Mr. Thomas Webster, the Right Honourable Joseph Napier, Sir W. G. Armstrong, Mr. W. Fairbairn, Mr. W. R. Grove, Mr. James Heywood, and General Sabine be reappointed, for the purpose of taking such steps as may appear expedient for rendering the Patent Law more efficient for the reward of the meritorious inventor and the advancement of practical science; and that the sum of £30 be placed at their disposal for the purpose.

That the Committee on Steamship Performance be reappointed, consisting of the Duke of Sutherland, The Earl of Gifford, M.P., The Earl of Caithness, Lord Dufferin, Mr. W. Fairbairn, Mr. J. Scott Russell, Admiral Paris, The Hon. Captain Egerton, R.N., The Hon. L. A. Ellis, M.P., Mr. J. E. M'Connell, Mr. W. Smith, Professor J. Macquorn Rankine, Mr. James R. Napier, Mr. Richard Roberts; Mr. Henry Wright to be Honorary Secretary; and that the sum of £100 be placed at their disposal.

That a Committee, consisting of Messrs. W. Fairbairn, Joseph Whitworth, James Nasmyth, J. Scott Russell, John Anderson, and Sir W. G. Armstrong, be requested to cooperate with a Committee appointed by Section B, viz. Dr. Gladstone, Professor W. A. Miller, and Dr. Frankland, for the purpose of investigating the application of Gun Cotton to warlike purposes; and that the sum of £50 be placed at their disposal for the purpose.

That the Committee for Tidal Observations in the Humber, consisting of Mr. J. Oldham, Mr. J. F. Bateman, Mr. J. Scott Russell, and Mr. T. Thompson, be reappointed, to extend their observations to the Trent and the Yorkshire Ouse; and that the sum of £50 be placed at their disposal for the purpose.

That Sir John Rennie, Mr. John Scott Russell, and Mr. C. Vignoles (with power to add to their number), Mr. G. P. Bidder, Jun., as Secretary, be a Committee to inquire and report as to the effect upon the Tides in the Nene and the Ouse by the opening of the Outfalls below Wisbeach and Lynn to the Wash; and that the sum of £25 be placed at their disposal for the purpose.

That the Committee for investigating the causes of Railway Accidents, consisting of Mr. W. Fairbairn, Mr. J. E. McConnell, and Mr. W. Smith, be reappointed; and that the sum of £25 be placed at their disposal for the purpose.

Applications for Reports and Researches not involving Grants of Money.

That Mr. Johnstone Stoney be requested to continue his Report on Molecular Physics.

That Mr. James Cockle be requested to prepare a Report on the History of the Theory of Equations.

That a Committee be appointed for the purpose of carrying into effect the objects of the Report on Scientific Evidence in Courts of Law.

That Dr. Gray, Dr. Sclater, Mr. Alfred Newton, and Mr. Wallace be a Committee to report on the Acclimatization of Domestic Quadrupeds and Birds, and how they are affected by migration.

That Dr. Gray, Professor Babington, and Mr. Newbold be a Committee to report on the Plants of Ray's 'Synopsis Stirpium,' for the examination of the original Herbaria of Ray, Richardson, Buddle, Plukenet, and others.

That Dr. Collingwood, Mr. J. A. Turner, M.P., Mr. James Heywood, Mr. John Lubbock, Mr. J. Gwyn Jeffreys, Mr. R. Patterson, Mr. P. P. Carpenter, and the Rev. H. H. Higgins be a Committee to inquire into the best mode of promoting the advancement of Science by means of the Mercantile Marine.

That Mr. Consul Swinhoe and Dr. Sclater be a Committee to report on the Zoology of the Island of Formosa.

That Dr. Edward Smith be requested to prepare for the next Meeting of the British Association a Report on the present state of our knowledge upon Nutrition, and especially its relation to Urea.

That the Rev. W. Vernon Harcourt, Right Hon. Joseph Napier, Mr. Tite, M.P., Professor Christison, Mr. J. Heywood, Mr. J. F. Bateman, Mr. T. Webster (with power to add to their number) be a Committee for the purpose of giving effect to the Report of the Committee on Technical and Scientific Evidence in Courts of Law.

Involving Applications to Government or Public Institutions.

That a Deputation, consisting of Mr. E. Chadwick, C.B., Mr. J. Heywood, Mr. Marsh, M.P., Dr. Farr, Mr. Tite, M.P., Mr. S. Gregson, M.P., and Col. Sykes, M.P., be requested to wait upon the Secretary of State for the Home Department and the Registrar-General, and represent to them the importance of having prepared Mortuary Statistics in respect to Classes and Occupations, in such forms as were recommended by the International Statistical Congress, or in such other form as will distinguish the Occupations or the Classes of those who die.

That the Committee, consisting of Dr. Robinson, Professor Wheatstone, Dr. Gladstone, and Professor Hennessy, which was appointed at Manchester to confer as to Experiments on Fog Signals, and to act as a Deputation to the Board of Trade, be requested to impress upon the Board the importance of inquiries on the subject.

Communications to be printed entire among the Reports.

That the Extract of Professor De Souza's Report to the Portuguese Government, regarding the Instruments used at Kew Observatory, be printed entire in the Reports.

That Mr. Symons's Papers on Rainfall be printed entire among the Reports.

That the Paper by the Astronomer Royal, on the Strains in the interior of Beams and Tubular Bridges, be printed entire among the Reports.

That Mr. Aston's Paper on Projectiles, with reference to their Penetration, be printed entire among the Reports.

That Mr. W. Fairbairn's Paper on the Results of some Experiments on the Mechanical Properties of Projectiles be printed entire among the Reports.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Cambridge Meeting in October 1862, *with the name of the Member who alone, or as the First of a Committee, is entitled to draw the Money.*

Kew Observatory.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
House for the Photoheliograph at Kew	100	0	0

Mathematics and Physics.

	£	s.	d.
Williamson, Prof.—Electrical Standards	100	0	0
Williamson, Prof.—For constructing and distributing ditto	50	0	0
Sykes, Col.—Balloon Ascents	200	0	0
Sykes, Col.—Balloon Committee (deficiency)	70	0	0
Sykes, Col.—Other expenses of Balloon Ascents	25	0	0
Glaisher, Mr.—Meteors	20	0	0
Jenkin, Mr.—Thermo-Electricity	15	0	0
Carried forward	£1180	0	0

	£	s.	d.
Brought forward	1180	0	0
Hennessy, Prof.—Vertical Atmospheric Movements	20	0	0
Chemistry.			
Matthiessen, Dr.—Alloys	20	0	0
Dupré, M.—Carbon under pressure	10	0	0
Gages, Mr.—Chemistry of Rocks	8	0	0
Geology.			
Scott, Mr.—Granites, &c.	5	0	0
Sorby, Mr.—Fusion of Rocks	30	0	0
Huxley, Prof.—Coal Fossils	20	0	0
Mallet, Mr.—Volcanic Temperature	100	0	0
Zoology and Botany.			
Cobbold, Mr.—Entozoa	25	0	0
Huxley, Prof.—Herrings	20	0	0
Jeffreys, Mr.—Dredging (Doggerbank)	25	0	0
Jeffreys, Mr.—Dredging (Shetland)	50	0	0
Jeffreys, Mr.—Dredging (N.E. coast of Scotland)	25	0	0
Jeffreys, Mr.—Committee for Dredging	10	0	0
Smith, Dr. E.—Prison Discipline	20	0	0
Gibb, Dr.—Bromide of Ammonium	8	0	0
Carpenter, Dr.—Foraminifera	25	0	0
Allman, Prof.—Hydroids	10	0	0
Mechanics.			
Webster, Mr.—Patent Laws	30	0	0
Sutherland, Duke of.—Steamships	100	0	0
Gladstone, Dr.—Gun Cotton	50	0	0
Oldham, Mr.—Tidal Observations	50	0	0
Rennie, Mr.—Action of Tides below Wisbeach to the Wash	25	0	0
Fairbairn, Mr.—Railway Accidents	25	0	0
Total	1891	0	0

General Statement of Sums which have been paid on Account of Grants for Scientific Purposes.

1834.

	£	s.	d.
Tide Discussions	20	0	0

1835.

	£	s.	d.
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0

1836.

	£	s.	d.
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain-Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£434	14	0

1837.

	£	s.	d.
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	89	5	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£918	14	6

1838.

	£	s.	d.
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Subterranean Temperature	8	6	0
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
Thermometers	16	4	0
	£956	12	2

1839.

	£	s.	d.
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast Iron Experiments	100	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-vessels' Engines	100	0	0
Stars in Histoire Céleste	331	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	6	16	6
Animal Secretions	10	10	0
Steam-engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0

1840.

	£	s.	d.
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4

1841.

	£	s.	d.
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0

	£	s.	d.
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	0
Railway Sections	38	1	6
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Cooperation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Cooperation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East coast of Scotland	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment in Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3

	£	s.	d.
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology 1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	3
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument, 1842	10	3	6
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£830	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1839	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	3
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1839	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogues of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on account of Anemometrical Observations	13	9	0
	£159	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0

	£	s.	d.
Periodical Phenomena	15	0	0
Meteorological Instrument, Azores	25	0	0
	£345	18	0

1851.

Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7

1852.

Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

1853.

Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0

1854.

Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7

1855.

Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4

1856.

	£	s.	d.
Maintaining the Establishment at Kew Observatory:— 1854......£ 75 0 0 1855......£500 0 0	575	0	0
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	9
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9

1857.

Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-Boats	5	0	0
	£507	15	4

1858.

Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2

1859.

Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1

1860.	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£1241	7	0

1861.	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee:— 1860 ...... £50 0 0 1861 ...... £22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahago	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	1
Constituents of Manures	25	0	0
	£1111	5	10

1862.	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland	25	0	0
Connexion of Storms	20	0	0
Dredging North-East Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-Electric Currents	5	0	0
	£1293	16	6

Extracts from Resolutions of the General Committee.

Committees and individuals, to whom grants of money for scientific purposes have been entrusted, are required to present to each following meeting of the Association a Report of the progress which has been made; with a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of pecuniary aid for scientific purposes from the funds of the Association expire at the ensuing meeting, unless it shall appear by a Report that the Recommendations have been acted on, or a continuation of them be ordered by the General Committee.

In each Committee, the Member first named is the person entitled to call on the Treasurer, William Spottiswoode, Esq., 19 Chester Street, Belgrave Square, London, S.W., for such portion of the sum granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named shall be deemed to include, as a part of the amount, the specified balance which may remain unpaid on the former grant for the same object.

General Meetings.

On Wednesday Evening, October 1, at 8 P.M., in the New Assembly Room, Guildhall, William Fairbairn, Esq., F.R.S., resigned the office of President to the Rev. R. Willis, M.A., F.R.S., who took the Chair, and delivered an Address, for which see page li.

On Thursday Evening, October 2, at 8 P.M., in the New Assembly Room, Guildhall, Professor Tyndall, F.R.S., delivered a Discourse on the Forms and Action of Water.

On Friday Evening, October 3, at 8 P.M., a Soirée, with Experiments, took place in the New Assembly Rooms.

On Monday Evening, October 5, at 8 P.M., Dr. Odling, F.R.S., delivered a Discourse on Organic Chemistry.

On Tuesday Evening, October 6, at 8 P.M., a Soirée, with Microscopes, took place in the New Assembly Rooms.

On Wednesday, October 7, at 3 P.M., the concluding General Meeting took place, when the Proceedings of the General Committee, and the Grants of Money for Scientific purposes, were explained to the Members.

The Meeting was then adjourned to Newcastle-on-Tyne*.

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* The Meeting is appointed to take place on Wednesday, August 26, 1863.

ADDRESS

BY

THE REV. R. WILLIS, M.A., F.R.S.,

Jacksonian Professor, &c.

Gentlemen of the British Association,—I have the honour to announce to you that we are now opening the Thirty-second Meeting of the British Association, and are for the third time assembled in this University.

At its first coming hither in 1833 its organization was scarce completed, its first Meeting having been devoted to explanations, discussions, and allotment of work to willing labourers; its second Meeting, to the reception of the first instalment of those admirable preliminary Reports which served as the foundation of its future labours, and to the division of scientific communications to the Sectional Committees.

But it was at Cambridge that the original plan of the Association bore fruit, by the receipt of the first paper which contained the results of experiments instituted expressly at the request of the Association. The success of the Association was now confirmed by the number of compositions and annual subscriptions paid in, and by the help of these funds a most important measure was introduced, namely, the practice of granting, in aid of philosophical researches to be undertaken by individuals or committees at the request of the Association, sums of money to meet the outlay required for apparatus or other expenses, which could not be asked from persons who were otherwise willing to devote their time to the advancement of science. It was at Cambridge that the importance and authority of the Association had become so manifest, that the first of its applications for Government assistance towards scientific objects was immediately complied with by a grant of £500 to reduce the Greenwich Observations of Bradley and Maskelyne. At the third Meeting improvements were made in the distribution of the Sciences to the Sections, and a Section of Statistics added. The only change in this respect that was subsequently found necessary was the establishment of a separate Section for Mechanical Science applied to the Arts, in 1837. The employment of alphabetical letters to distinguish the Sections had been introduced in 1835.

I have said enough to claim for the Cambridge Meeting the honour of completing the development of the Association; and I may be permitted to quote from our fourth Report the gratifying assurance, that so obvious was the utility of the proposed undertaking, that, in its very infancy, there were found several distinguished individuals, chiefly from the University of Cambridge, who volunteered to undertake some of the most valuable of those Reports which appeared in the first volume of the Proceedings.

With a mixture of regret and shame I confess, that although my name is enrolled in the honourable list of those who undertook Reports, it will be sought in vain amongst those who promptly performed their promises. Yet I may be permitted to say that I still hope to be enabled at some future time to complete the Report on Acoustics, of which I delivered merely an oral sketch at the second Meeting of the Association, in 1832.

The Association quitted Cambridge to pursue, with its matured organization, and with continually increasing stability and influence, the career of brilliant and useful labours in every branch of Science that it has never ceased to run during the two-and-thirty years that have elapsed since its foundation. It revisited Cambridge after an interval of twelve years, in 1845; and now, after a lapse of seventeen years, we have the high gratification of welcoming once more the Association to this scene of its early meetings.

This appears a fitting occasion for a concise review of the leading principles and prominent labours of the body.

Scientific Societies, as usually constituted, receive and publish papers which are offered to them by individuals, but do not profess to suggest subjects for them, or to direct modes of investigation, except in some cases by offering prizes for the best Essay in some given branch.

This Association, on the contrary, is not intended to receive and record individual originality. Its motto is, SUGGESTION AND COOPERATION, and its purpose is thus to advance science by cooperation, in determinate lines of direction laid down by suggestion.

To give form and authority to this principle, the admirable conception of suggestive Reports was in the first place developed; a collection that should constitute a general survey of the Sciences as they stood at the foundation of the Association, each branch reported by some member who had already shown his devotion to the cultivation of it by his own contribution to its advancement, and each Report passing in review its appointed subject, not for the purpose of teaching it, but of drawing forth the obscure and weak places of our knowledge of it, and thus to lay down the determinate lines of direction for new experimental or mathematical researches, which it was the object of the Association to obtain.

The requests for these Reports were zealously responded to, and so rapidly that at the second Meeting ten were received, and at the third eight others. In this manner in five or six years the cycle of the Sciences was well nigh exhausted; but the series of such Reports has been maintained in succeeding years, even to the present time, by the necessity of supplemental Reports, to point out not merely the advances of each science already treated, but the new lines of direction for inquiry that develope themselves at every step in advance.

The Reports thus described were entitled "On the progress and desiderata of the respective branch of Science," or "On the state of our knowledge respecting such Science," and must be considered as merely preparations for the great work for which the Association was formed. They constitute the suggestive part of the scheme: the cooperative mechanism by which each new line of research recommended in the Reports was to be explored, was energetically set in motion by the annual appointment of Committees or individuals to whom these especial investigations were respectively assigned, with adequate sums at their disposal.

These Committees were requested to report their labours from year to year, and thus a second set of documents have been produced, entitled "Reports of Researches undertaken at the request of the Association," which are entirely distinct from the "suggestive Reports," but immediately derived from them, and complementary to them.

Such is a concise view of the system at first laid down by the wisdom of our founders, and which, with some modifications, has produced the inestimable contents of our printed volumes. In practice the "suggestive Report" is often a paper contributed by some able investigator to some meeting of the Association, which produces a request from the body that he will pursue his researches with their sanction and assistance, and write a Report complementary to his own suggestions.

Again, although we did not profess to receive and publish individual researches, the number of these received at each meeting is very great; the merit of some of them so eminent, that they are authorized to be printed entire amongst the Reports; and the Notices and Abstracts of the remainder, which at first occupied a small proportional part of each volume, now occupy nearly half of it.

I will now direct your attention to the principal objects to which our funds have been directed.

To appreciate the value of an investigation by the money it costs, may appear at first sight a most unworthy test, although it be a thoroughly British view of the subject.

But there are undoubtedly a great number of most important inquiries in science that are arrested, not for want of men of zeal and ability to carry them out, but because from their nature they require an outlay of money beyond the reach of the labourers who ardently desire to give their time and thoughts to them, and because the necessity and value of the proposed investigation are wholly unappreciable by that portion of society who hold the purse-strings.

But it is in the cases above alluded to of expensive investigation that the direct use and service of our body has been made the most manifest. The British Association holds its own purse-strings, and can also perfectly understand when they should be relaxed. Nay, more, by its influence and character, established by the disinterested labours and successful exertions of more than thirty years, it may be said to command the national funds; for the objects in aid of which Government assistance has been requested, have been so judiciously chosen, that such applications have very rarely been unsuccessful, but have been, on the contrary, most cordially acceded to.

Indeed it may be observed, that from the period of the foundation of the Association the Government of this country has been extending its patronage of Science and the Arts. We may agree with the assertion of our founder, Sir David Brewster, in supposing that this change was mainly effected by the interference of this Association and by the writings and personal exertions of its members.

For the above reasons it appears to me that by a concise review of the principal objects to which the funds of our body have been applied, and of those which its influence with the Government has forwarded, we obtain a measure of the most important services of the British Association.

But in considering the investigations carried out by committees or individual members by the help of the funds of the Association, it must always be remembered that their labours, their time and thoughts, are all given gratuitously.

One of the most valuable gifts to Science that has proceeded from our Association is the series of its printed Reports, now extended to thirty volumes. Yet these must not be supposed to contain the complete record even of the labours undertaken at the request and at the expense of the body. Many of these have been printed in the volumes of other societies, or in a separate form. Several, unhappily, remain in manuscript, excluded from the public by the great expense of publication.

I am the more induced to direct attention to this great work at present because I hold in my hand the first printed sheets of a general Index to the series from 1831 to 1860, by which the titles and authors of the innumerable Memoirs upon every possible scientific subject, which are so profusely but promiscuously scattered through its eighteen thousand pages, are reduced to order, and reference to them rendered easy. This assistance is the more necessary because so many investigations have been continued with intermissions through many years, and the labour of tracing any given one of them from its origin to its termination through the series of volumes is extremely perplexing.

For this invaluable key to the recorded labours of the Association we are indebted to Professor Phillips, and the prospect of its speedy publication may be hailed as a great subject of congratulation to every member of our body.

In every annual volume there is a table of the sums which have been paid from the beginning on account of grants for scientific purposes. The amount of these sums has now reached £20,000; and an analysis of the objects to which this expenditure is directed will show that if we divide this into eighteen parts, it will appear, speaking roughly, that the Section of Mathematics and Physics has received twelve of these parts, namely two-thirds of the whole sum, the Sections of Geology and Mechanical Science two parts each, while one part has been given to the Section of Botany and Zoology, and one divided among the Sections of Chemistry, Geography, and Statistics.

The greater share assigned to the first Section is sufficiently accounted for by the number and nature of the subjects included in it, which require innumerable and expensive instruments of research, observatories, and expeditions to all parts of the globe.

If we examine the principal subjects of expenditure, we find, in the first place, that more than £1800 was expended upon the three Catalogues of Stars, namely, the noble Star Catalogue, which bears the name of the British Association, commenced in 1837, and completed in eight years, and the Star Catalogues from the observations of Lalande and Lacaille, commenced in 1835 and 1838, and reduced at the expense of the British Association, but printed at the expense of Her Majesty's Government. £150 was applied principally to the determination of the Constant of Lunar Nutation, under the direction of Dr. Robinson, in 1857, and to several other minor Astronomical objects.

At the very first Meeting at York, the perfection of Tide Tables, Hourly Meteorological Observations, the Temperature of the atmosphere at increasing heights, of Springs at different depths, and observations on the Intensity of Terrestrial Magnetism, were suggested as objects to which the nascent organization of the Association might be directed.

Its steady perseverance, increasing power and influence as successive years rolled on, is marked by the gradual carrying out of these observations, so as to embrace nearly the whole surface of the globe.

Thus, under the direction of Dr. Whewell, a laborious system of observations, obtained by the influence and reduced at the expense of the Association, who aided this work with a sum of about £1300, has determined the course of the Tide-wave in regard to the coasts of Europe, of the Atlantic coast of the United States, of New Zealand, and of the east coast of Australia. Much additional information has been since collected by the Admiralty through various surveying expeditions; but it appears that much is still wanting to complete our knowledge of the subject, which can only be obtained by a vessel specially employed for the purpose.

More than £2000 have been allotted to Meteorology and Magnetism, for the construction of instruments, and the carrying out of series of observations and surveys in connexion with them. To this must be added a sum of between £5000 and £6000 for the maintenance of Kew Observatory, of which more anon. The advance made in these important sciences, through the labours of the Committees of the British Association, may be counted among the principal benefits it has conferred.

To the British Association is due, and to the suggestion of General Sabine, the first survey ever made for the express purpose of determining the positions and values of the three Isomagnetic Lines corresponding to a particular epoch over the whole face of a country or state.

This was the Magnetic Survey of the British Islands, executed from 1834 to 1838, by a Committee of its members, General Sabine, Prof. Phillips, Sir J. Ross, Mr. Fox, and Mr. Lloyd, acting upon a suggestion brought before the Cambridge Meeting in 1833. It was published partly in the volume for 1838, and partly in the Philosophical Transactions for 1849. This was followed by a recommendation from the Association to Her Majesty's Government, for the equipment of a naval expedition to make a magnetic survey in the southern portions of the Atlantic and Pacific Oceans. This recommendation, concurred in by the Royal Society, gave rise to the voyage of Sir James Clark Ross in the years 1839 to 1843. In a similar manner was suggested and promoted the magnetic survey of the British possessions in North America, authorized by the Treasury in 1841; the completion of the magnetic survey of Sir James Ross, by Lieutenant Moore and Lieutenant Clark in 1845, in a vessel hired by the Admiralty; the magnetic survey of the Indian Seas, by Captain Elliot, in 1849, at the expense of the Directors of the East India Company; and the magnetic survey of British India, commenced by Captain Elliot in 1852, and completed between 1855 and 1858 by Messrs. Schlagintweit. Finally, in 1857 the British Association requested the same gentlemen who had made the survey of the British Islands in 1837, to repeat it, with a view to the investigation of the secular changes of the magnetic lines. This has been accomplished, and its results are printed in the new volume for 1861*.

The Association also, aided by the Royal Society, effected the organization in 1840 of the system of simultaneous Magnetical and Meteorological Observatories, established as well by our own Government as by the principal foreign Governments at different points of the earth's surface, which have proved so eminently successful, and have produced results fully equalling in importance and value, as real accessions to our knowledge, any anticipations that could have been formed at the commencement of the inquiry†.

General Sabine, whose labours have so largely contributed to these investigations, has given to the University an admirable exposition of the results during the present year, in the capacity of Sir Robert Rede's Lecturer.

In 1854, in consequence of representations originating with the British Association, our Government created a special department, in connexion with the Board of Trade, under Admiral FitzRoy, for obtaining Hydrographical and Meteorological observations at sea, after the manner of those which had been for some years before collected by the American Government at the instance and under the direction of Lieut. Maury.

Observations on the wind have been carried on by means of the various self-registering Anemometers of Dr. Whewell, Mr. Osler, Dr. Robinson, and Mr. Beckley, which instruments have been improved, tested, and thoroughly brought into practice by the fostering care of our body; and by the aid of its funds, experiments have been made on the subterranean temperature of deep mines; and on the temperature and other properties of the Atmosphere at great heights by means of Balloon Ascents. Four of these were made in 1852, in which heights between nineteen and twenty thousand feet were reached. But in the present year Mr. Glaisher has attained an altitude of nearly thirty thousand feet. We may hope that some account of this daring achievement, and its results to science, may be laid before the Association at its present Meeting.

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* *Vide* volume for 1859, p. xxxvii.

† Report, 1858, p. 298.

Earthquake shocks were registered in Scotland by a Committee of the Association, from 1841 to 1844; and Mr. Mallet commenced, in 1847, a most valuable series of Reports on the Facts and Theory of Earthquake Phenomena from the earliest records to our own time, which have graced our volumes even to the one last published.

One of the most remarkable and fruitful events in our history, in relation to Physical observations, is the grant by Her Majesty, in 1842, of the Observatory erected at Kew by King George the Third, which had been long standing useless. It gave to the Society a fixed position, a depository for instruments, papers, and other property, when not employed in scientific inquiry, and a place where Members of the Association might prosecute various researches. This establishment has been, during the twenty years of its existence, gradually moulded into its present condition of a most valuable and unique establishment for the advancement of the Physical Sciences.

After the first few years its existence was seriously perilled, for in 1845 the expediency of discontinuing this Observatory began to be entertained; but upon examination, it then appeared that the services to science already rendered by this establishment, and the facilities it afforded to Members of the Association for their inquiries, were so great as to make it most desirable to maintain it. Again, in 1848, the burthen of continuing this Observatory in a creditable state of efficiency pressed so heavily upon the funds of the Association, then in a declining state, that the Council actually recommended its discontinuance from the earliest practical period. This resolution was happily arrested.

In 1850 the Kew Committee reported that the Observatory had given to science self-recording instruments for electrical, magnetical, and meteorological phenomena, already of great value, and certainly capable of great further improvement; and that if merely maintained as an *Experimental Observatory*, devoted to open out new physical inquiries and to make trial of new modes of research, but only in a few selected cases to preserve continuous records of passing phenomena, a moderate annual grant from the funds of the Association would be sufficient for this most valuable establishment for the advancement of the Physical Sciences.

In this year it fortunately happened that Lord J. Russell granted to the Royal Society the annual sum of £1000 for promoting scientific objects, out of which the Society allotted £100 for new instruments to be tried at Kew, —the first of a series of liberal grants which have not only very greatly contributed to the increasing efficiency of the establishment, but have ensured its continuance. It now contains a workshop fitted with complete tools, and a lathe and planing machine, &c. by which apparatus can be constructed and repaired, and a dividing engine for graduating standard thermometers, all presented by the Royal Society. The work done, besides the maintenance of a complete set of self-recording magnetographs, established in 1857, at the expense of £250, by the Royal Society, consists in the construction and verification of new apparatus and in the verification of magnetic, meteorological and other instruments, sent for that purpose by the makers. For example, all the barometers, thermometers, and hydrometers required by the

Board of Trade and Admiralty are tested, standard thermometers are graduated, magnetic instruments are constructed, and their constants determined for foreign and colonial observatories, and sextants are also verified.

An example of its peculiar functions is given in the very last Report (1861), where it appears that an instrument contrived by Professor William Thomson, of Glasgow, for the photographic registration of the electric state of the atmosphere, has been constructed by Mr. Beckley in the workshop of this Observatory, with mechanical arrangements devised by himself, and that it has been in constant and successful operation for some time. Those who have experienced the difficulty of procuring the actual construction of apparatus of this kind devised by themselves, and the still greater difficulty of conveniently carrying out the improvements and alterations required to perfect it when brought into use, will agree that the scientific importance and utility of an establishment cannot be overrated, in which under one roof are assembled highly skilled persons not only capable of making and setting to work all kinds of instruments for philosophical research, but also of gradually altering and improving them, as experience may dictate.

The creation of this peculiar Observatory must be regarded as one of the triumphs of the British Association.

As far as the Association is concerned, its maintenance has absorbed between five and six thousand pounds, the annual sum allotted to it from our funds having for each of the last six years reached the amount of £500.

The construction of the Photoheliograph may be also quoted as an example of the facilities given by this establishment for the developing and perfecting of new instruments of observation.

A suggestion of Sir John Herschel in 1854, that daily photographs of the sun should be made, has given birth to this remarkable instrument, which at first bore the name of the Solar Photographic Telescope, but is now known as the Kew Photoheliograph. It was first constructed under the direction of Mr. De la Rue by Mr. Ross. The British Association aided in carrying out this work by assigning the dome of the Kew Observatory to the instrument, and by its completion in 1857 in their workshops by Mr. Beckley the assistant; but the expense of its construction was supplied by Mr. Oliveira, amounting to £180. This instrument was conveyed to Spain under the care of Mr. De la Rue on occasion of the eclipse in 1860, who most successfully accomplished the proposed object by its means, and it was replaced at Kew on his return. But to carry on the daily observations for which it was constructed requires the maintenance of an assistant, for which the funds of the Association are inadequate, although it has already supplied more than £200 for that purpose. Mr. De la Rue, in consequence of the presence of the Heliograph at Kew being found to interfere with the ordinary work of the establishment, has kindly and generously consented to take charge for the present of the instrument and of the observations, at his own Observatory, where celestial photography is carried on. But it is obvious that the continuation of these observations for a series of years, which is necessary for obtaining the desired results, cannot be hoped for unless funds are provided.

I cannot conclude this sketch of the objects in the Physical Section to which the funds of the Association have been principally devoted, without alluding to Mr. Scott Russell's valuable experimental investigations on the motion and nature of waves, aided by £274.

If we now turn to Geology we find £2600 expended, of which £1500 were employed in the completion of the Fossil Ichthyology of Agassiz, and upon

Owen's Reports on Fossil Mammalia and Reptiles, with some other researches on Fossils.

The remainder was principally devoted to the surveys and measurement, in 1838, of a level line for the purpose of determining the permanence of the relative level of sea and land, and the mean level of the Ocean; and to the procuring of drawings of the geological sections exposed in railroad operations before they are covered up—a work which was carried on from 1840 to 1844, when the drawings were deposited in the Museum of Practical Geology, and the further continuance of it handed over to the geological surveyors of that establishment.

£2300 have been devoted to the carrying out of various important experimental investigations in relation to the Section of Mechanical Science.

Of this sum £900 were paid between 1840 and 1844, in aid of a most important and valuable series of experiments on the Forms of Vessels, principally conducted by Mr. Scott Russell, in connexion with the experiments on Waves. This investigation was ready for press in 1844, but it is greatly to be regretted that the great expense of printing and engraving it has hitherto prevented its publication.

Nearly the same sum has given to us various interesting and instructive experiments and facts relating to steam-engines and steam-vessels, carried on by different Committees from 1838 to the present time; amongst which may be especially noted the application of the Dynamometric instruments of Morin, Poncelet, and Moseley, to ascertain the Duty of Steam-engines, from 1841 to 1844.

Experiments on the Strength of Materials, the relative strength of Hot and Cold Blast Iron, the effect of Temperature on their tensile strength, and on the effect of Concussion and Vibration on their internal constitution, carried on principally by our late President and by the late Mr. Eaton Hodgkinson, at different intervals from 1838 to 1856, have been aided by grants amounting to £400.

The remainder of the sum above mentioned was principally devoted to the experimental determination of the value of Railway Constants, by Dr. Lardner and a Committee in 1838 and 1841.

The Section of Botany, Zoology, and Physiology has absorbed about £1400, of which nearly £900 have been applied to Zoology, partly for the expense of Dredging Committees for obtaining specimens of Marine Zoology on our own coasts and in the Mediterranean and other localities—whose useful labours have been regularly reported from 1840 to 1861—but principally for zoological researches in different districts and countries.

In Botany may be remarked the labours of a Committee, consisting of Professors Daubeny and Henslow and others, formed in 1840, to make experiments on the preservation of Vegetative Powers in Seeds; who continued their work for sixteen successive years, reporting annually, and assisted by a sum of £100. The greatest age at which the seeds experimented upon was found to vegetate was about forty years.

Another Committee, with Mr. Hunt, was engaged during seven years, from 1841, in investigating the influence of coloured light on the germination of seeds and growth of plants.

These are specimens of the admirable effect of the organization of our Association in stimulating and assisting with the funds the labours of investigators in new branches of experimental inquiry.

It would occupy too much time to particularize a variety of interesting researches in the remaining sections of Chemistry and in the sections of

Statistics, Geography, and Ethnology, to which small sums have been assigned.

The newly issued Report of our Manchester Meeting is admirably calculated to maintain the reputation of the Association. Besides a number of excellent Reports which are the continuation of researches already published in our volumes, it contains elaborate and important Reports by Mr. Stewart on the Theory of Exchanges in Heat; by Dr. Smith and Mr. Milner on Prison Diet and Discipline; by Drs. Schunck, Angus Smith, and Roscoe on the progress of Manufacturing Chemistry in South Lancashire; Mr. Hunt on the Acclimatization of Man; Dr. Sclater and M. Hochstetter on the Apteryx of New Zealand; Professor Phillips and Mr. Birt on the Physical Aspect of the Moon. Professor Owen contributes a most interesting paper on the Natives of the Andaman Islands. The President of the Royal Society reports the Repetition Magnetic Survey of England; and Mr. Fairbairn, our late President, reports on the Resistance of Iron-Plate Pressure and Impact.

The Transactions of the Sections occupy nearly as much space as the Reports, and are replete with valuable and original matter, which it would be impossible to particularize.

Many of my predecessors in their Addresses have alluded to the most striking advances that have been made in the various sciences since the last Meeting; I will mention a few of these in Astronomy, Chemistry, and Mechanics.

In ASTRONOMY, M. Delaunay has communicated to the Academy of Sciences of Paris the results of his long series of calculations in the Lunar Theory, destined to fill two volumes of the Memoirs of the Academy. The first volume was published in 1861; the printing of the other is not yet begun. This theory gives the expressions for the three coordinates of the moon under an analytic form, and carries those for longitude and latitude to terms of the seventh order inclusive, that of Plana extending generally only to terms of the fifth order. The addition of two orders has required the calculation of 1259 new terms for the longitude, and 1086 new terms for the latitude. It was by having recourse to a new process of calculation, by which the work was broken up into parts, that M. Delaunay has been able to advance the calculation of the lunar inequalities far beyond the limits previously reached.

The Earl of Rosse has given to the Royal Society (in a paper read June 20, 1861) some further account of researches in Sidereal Astronomy carried on with a Newtonian telescope of six-feet clear aperture. These researches are prefaced by an account of the process by which the six-feet specula were made, a description of the mounting of the instrument, and some considerations relative to the optical power it is capable of. A selection from the observations of nebulæ is given in detail, illustrated by drawings, which convey an exact idea of the bizarrerie and astonishing variety of form exhibited by this class of cosmical bodies.

Argelander, the eminent director of the Observatory at Bonn, is carrying on with great vigour the publication of his Atlas of the Stars of the Northern Heavens within 92° of Polar Distance. A large portion of this enormous work is completed, and two volumes, containing the data from observation for the construction of the Charts, were recently published. These volumes contain the approximate places of 216,000 stars situated between the parallels of 2° south declination and 41° north declination.

Simultaneously with the construction of Star-charts, among which those of M. Chacornac of the Paris Observatory deserve particular mention, additions have been made to the number of the remarkable group of small planets between the orbits of Mars and Jupiter, their discovery being facilitated by the use of charts. The last announced, which is No. 74 of the Series, was discovered on the morning of Sept. 1 of this year, by M. Luther of Bilk, near Düsseldorf, whose diligence has been rewarded by the discovery of a large number of others of the same group.

The present year has been signalized by the unexpected appearance of a comet of unusual brightness, which, although its tail was far from being as conspicuous as those of the comets of 1858 and 1861, exhibited about its nucleus phenomena of a distinct and remarkable character, the records of which may possibly at some future time aid in the discovery of the nature of that mysterious action by which the gaseous portion of these erratic bodies is so strangely affected.

On an application made by the Council of the Royal Astronomical Society, Government has granted £1000 for the establishment, during a limited period, under the superintendence of Captain Jacob, of an Observatory at a considerable altitude above the level of the sea, in the neighbourhood of Bombay. The interesting results of the ascent by Professor Piazzi Smyth a few years since of the Peak of Teneriffe, for the purpose of making astronomical and physical observations, suggested to the President and Council of the Society the desirableness of taking this step.

In CHEMISTRY, the greatest advance which has been made during the past year is probably the formation of compounds of Carbon and Hydrogen by the direct union of those elements. M. Berthelot has succeeded in producing some of the simpler compounds of carbon and hydrogen by the action of carbon intensely heated by electricity or hydrogen gas; and from the simpler compounds thus formed he is able to produce, by a succession of steps, compounds more and more complex, until he bids fair to produce from inorganic sources all the compounds of carbon and hydrogen which have hitherto been only known as products of organic origin. Mr. Maxwell Simpson has also added to his former researches a step in the same direction, producing some organic products by a synthetical process. But these important researches will be fully laid before you in the lecture on Organic Chemistry which Dr. Odling has kindly promised for Monday evening next.

Dr. Hofmann has continued his indefatigable researches on Poly-ammonias, as well as on the colouring matters produced from coal-tar. M. Schlœsing proposes a mode of preparing chlorine by a continuous process, which may perhaps become important in a manufacturing point of view. In this process nitric acid is made to play the same kind of part that it does in the manufacture of sulphuric acid, the oxides of nitrogen acting together with oxides of manganese as carriers of oxygen from the atmosphere to the hydrochloric acid.

The methods of dialysis announced last year by the Master of the Mint, and of spectrum analysis are now in everybody's hands, and have already produced many interesting results.

In CIVIL OR MECHANICAL ENGINEERING there is nothing very new.

The remarkable series of experiments carried on at Shoeburyness and elsewhere have developed many most interesting facts and laws in relation to the properties of iron, and its resistance to projectiles at high velocities, which will doubtless be fully laid before you at some future period; but in the present imperfect state of the investigation, and in consideration of the purpose of that investigation, prudential reasons forbid the complete publication of the facts. My able predecessor in this Chair, who has taken so prominent a part in these experiments, has given an account of some of the results in a communication to the Royal Institution in May last, and also in the new volume for 1861; and is, as he informs me, engaged with a long series of experiments on this subject, which, with his experience and ability, cannot fail to develope new facts, and will, in all probability, ultimately determine the law of penetration.

In London we may direct attention to the commencement of the Thames Embankment and to the various works in progress for the concentration of the Metropolitan Railways; especially to the proximate completion of the Underground Railway. The lamentable disaster in the Fens of last summer has been most ably subdued, but the remedial measures adopted are not fully completed, and the interests involved are of so great a magnitude and complexity, that it is scarcely possible for this event to be discussed on the present occasion with due impartiality.

The magnificent collection of machinery in the Great Exhibition shows a great advance in construction; but this is not the proper occasion to enter in detail into the various contrivances and processes which it displays.

Before I conclude I have the painful duty of reminding you that since our last meeting we have had to deplore the loss of that most illustrious patron of science and art, His Royal Highness the Prince Consort, the President of our Association at Aberdeen and the Chancellor of this University. In the latter capacity he afforded us many opportunities of observing his scientific attainments and genuine zeal and love for all branches of knowledge: his gracious kindness and respect to men of science and literature have left an impression upon us that can never be effaced.

I must also ask a tribute to the memory of our late Professors of Chemistry and Botany, both of whom have done in their lifetime excellent good service to science, and especially to the British Association; Professor Cumming by contributing one of the invaluable primary Reports upon which our proceedings were based, as well as other communications; Professor Henslow by various Reports, some of which I have already alluded to. We have had also to lament the loss of that able scientific navigator, Sir J. Clark Ross.

It remains for me to express my sense of the high and undeserved honour conferred upon me by the position in which you have placed me, and in the name of the University to welcome you hither, and wish you a prosperous and fruitful meeting, alike conducive to the progress of science and impulsive to its cultivation in the place of your reception.

REPORTS

ON

THE STATE OF SCIENCE.

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UNIVERSITY OF CALIFORNIA

Report on Observations of Luminous Meteors, 1861-62. *By a Committee, consisting of* James Glaisher, *F.R.S., F.R.A.S., Secretary to the British Meteorological Society, &c.;* R. P. Greg, *F.G.S. &c.;* E. W. Brayley, *F.R.S. &c.; and* A. Herschel.

The Committee are indebted to Members of the Association and to other observers for a larger number of observations bearing upon individual meteors than has fallen to their lot to assemble during previous years. They may be counted as follows:—(A) Meteor 1, July 16th, eight accounts; (B) meteor 2, July 16th, thirteen accounts; (C) meteor, August 6th, three accounts; (D) meteor, November 12th, eight accounts; (E) meteor, November 19th, eleven accounts; (F) meteor, December 8th, twenty-eight accounts; (G) meteor, February 2nd, 1862, eleven accounts; (H) meteor, February 23rd, 1862, five accounts. Of the small shooting-stars, double observations only are found. The discussion of these observations follow the Catalogue in Appendix I.

Eight accounts of one and thirteen of the second of the meteors visible on the evening of July 16th, 1861, show those of the Duke of Argyll and Mr. Frost to have been distinct meteors, succeeding each other with an interval of more than an hour. The accounts are embodied in the present Catalogue, and the results discussed in Appendix I.

Of the meteor August 6th, a further account from excellent observers in London, has afforded a good determination; the accounts and their interpretation are presented in the Catalogue and Appendix I.

Numerous accurate observations of shooting-stars of the 10th August, period 1861, too voluminous for separate insertion in the Catalogue, have been collected and examined for accordances, and the accordant observations only entered in the Catalogue, together with individual observations which appeared of particular interest from among the entire number; the results of the accordant observations are tabulated in Appendix I.

A CATALOGUE OF OBSERVATIONS

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861. July 16	h m 9 30 p.m.	Weston-super-Mare. (Also seen in Dorsetshire.)	Large as Venus at max.	Duller than Venus at max. brilliancy.	3 or 4 seconds; moving slowly.	Exploded when altitude 45°.
16	9 58 p.m.	Whitehall, London.	Very large ball, but not quite full.	Very brilliant..	Slower than meteors usually move; "leisurely."	Began almost and disappear behind the houses on west side Whitehall.
16	Exactly 10 p.m.	Gainford, Darlington, Yorkshire.	Like Jupiter, seen in a good telescope, but not exactly spherical.	....	Motion not rapid.	From 10° below Aquilæ, throu the E. to N. from altitude to about altitu 20°.
16	....	*Greenwich* and	*Kensington.* Alrea	dy inserted,	p. 10 *of Report*	*for* 1861 ....
16	Soon after 10 p.m.	Derby	Like a rocket	?	Endured very long, about 15 seconds.	Went N. ....
16	10 p.m., or 15m. after 10 p.m.	Southborough, Tunbridge-wells.	?	?	A companion of the observer *walking* (at call) 13 or 14 yds. from another room, saw the spark which was cast off at the close.	From S.E. to Came from a wing of house; dis peared some lit distance ab the horizon.
16	Between 10 p.m. and half-past.	Whitburn, near Sunderland, Durham.	Like ball of quicksilver, or an enormous star.	?	?	Due E............
16	About 10 40 p.m.	Furness Abbey, Lancashire.	Threw a strong light.	?	Moved very slowly; "gracefully"	From behind a south of Abbey; Nor ward through lost behind tr
16	?	Penmaen-Mawr, Conway, N. Wales.	Very large	?	Very slow in its motion, "quiet and deliberate."	Over the hills and S. of P maen-Vach; appeared beh Penmaen-Vac

OF LUMINOUS METEORS.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
White train 8° in length attended the nucleus. Burst into sparks which continued 3 seconds, advancing 10° before they disappeared.	?	Appeared in the N.W.		Personal accounts to W. H. Wood.
Carried a blunted or spread tail 15 or 20 times longer than the head.		Downwards at an angle of 25° to the horizon.	Point of observation was facing the National Gallery, near the top of Parliament Street.	Charles Reed.
hortly before disappearing threw off a part of its substance, which followed it closely like a lesser luminary till both were suddenly extinguished in a sudden and peculiar manner in clear sky. A track of light endured for some seconds at this part of the path.	About 90°	First horizontal, then declining slightly.		Mrs. E. Addison.
				J. Howe; Duke [of Argyll.
isappeared in mid-air, like a Roman candle ball; but the train which pursued it did not look exactly like sparks.	60°	Horizontal, or very slightly declining at last.		John Borough.
Majestic." Left a track of light behind it, but no sparks till just before it disappeared, when one spark was cast off from it.	?	Came over from the right of the house, descending as a rocket in the form of an arch.	Open bay-window faced N.N.E.	Mrs. Davies.
eaving no train. Sailing without change until it disappeared in a cloud.	?	Quite horizontal; from left to right.		M. M.
ollowed by a bright train: threw off no sparks.	?	Horizontal, or very slightly inclined towards the earth.		G. H. Chambers.
oman candle-ball. Phosphorescent train, closely adhering and sharply terminated, without sparks.	?	Slightly declining; perhaps curved downwards.	Point of observation upon the sands midway between Penmaen-Mawr and Penmaen-Vach.	H. H. Bemrose.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861. July 16	h m 11 0 p.m.	Bristol	Much > than any planet.	Clear bluish...	About 1½ sec.	? ....
16	11½ p.m. ...	Sittingbourne, Kent.	Threw a brilliant light when high in the heavens, expanding and increasing in brightness as it neared the horizon.	As it neared the horizon it assumed a beautiful blue colour.	?	Probably burst i view in th zenith. Fir seen high in th heavens, goin S.W. Lost i haze of th horizon.
16	11½ p.m. ...	Banbury	Like a toy balloon..	Bright clear blue and white.	?	3° above ε Pegas 3° above θ Aqu læ; 2° above Serpentis. He houses inte vened. Dev loped the t in the last 3 of the visib track.
16	11 30 p.m.	Frome	?	?	?	Disappeared a f degrees abo the horizon.
16	11½ p.m. ...	East Isley Downs, Newbury, Berks.	Large as a full moon, and more light.	?	?	Appeared near t meridian; dis peared behind cloud.
16	11½ p.m. ...	Brentwood	?	?	?	? ....
16	11½ p.m., or soon after.	Cheltenham......	?	?	Half a minute; steady and equable.	From about 4 altitude to ab 30° altitude.
16	11 32 p.m.	Flimwell, Hurst Green, Sussex.	Like Capella in the zenith. Lit up the clouds like crescent moon at 45°.	White in zenith and upon the clouds.	3 seconds from zenith to explosion.	Passed in zen between β γ D conis; bu about η Ophiu
16	11 33 p.m.	Sandown, Isle of Wight.	Large signal-rocket	?	?	From the zen near α Lyræ a few deg from the S. horizon.
16	11 33 p.m.	Tavistock Square, Euston Road, London.	A sudden luminosity overhead.	?	4 seconds from zenith to disappearance.	First seen 15° so of zenith; pa downwards rect thro Scorpio, and appeared the horizon.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
No sparks or train. Left a long clear white streak for some little time.	15° to 20° high.	Course from N. to S. ...	By letter to W. H. Wood, Weston-super-Mare.	J. Ellis.
Disappeared in haze of the horizon. At the point of disappearance the stream of light was visible for 5 minutes after.	?	Vertical	....	F. R. Cooper.
Track very bright, endured 3 minutes; like a half circular mark of phosphorus upon a wall.	?	Passed over from E. to S.W.	The curved tail was clearly seen by a companion called out of a house by the observer. Brightest in the Milky Way.	John Griffin, M.D.
Track of luminous matter; lasted 4 or 5 minutes; curiously contorted by degrees, as if by currents of air. Large body of sparks thrown off at disappearance.	?	?	....	William Dunn.
First emitted sparks; afterwards a bright train which endured some minutes.	....	Took a south-westerly course.	Saw at least 4 meteors, of more or less brilliancy, from 10½ to 12 p.m.	L. Lousley.
?	?	?	The time distinguishes this meteor from that of 10 p.m.	J. L. P.
Burst with few sparks. Track at the last visible some minutes.	90°	From the S.E. to S.W...	....	James Philps.
Only momentary; sparks seen in the zenith; white, and extending half ☽'s diameter to either side of the nucleus; not in front or behind. No track seen to remain.	90°	Nearly vertical to S.W. by W. or S.W.	Overcast W. and S.W., except near the zenith, where the meteor was lost at altitude 70°.	F. Howlett and A. S. Herschel.
Most brilliant track; visible for 5 minutes.	?	Nearly vertically downwards.	The track at first straight; soon curved opposite to the rising wind. Portions drifted fading into the Milky Way.	W. M. Frost.
Bright train visible several minutes. The lower portion took a crescent form, the horns drifting 15° or 20° S. into the Milky Way in 5 minutes before disappearance.	?	Vertically, S.W.	Probably originated in Andromeda.	T. Crumplen and J. Townsend (Assistants to Mr. Slater's Observatory, Euston Road).

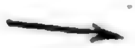
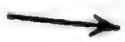
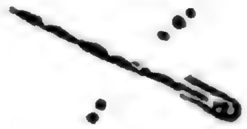
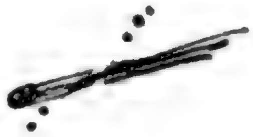
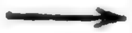
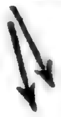
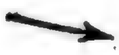
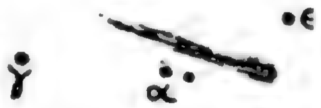
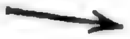
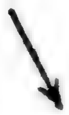
Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861.	h m					
July 16	11 34 p.m.	Between St. Albans and Barnet.	?	?	....	Originated unde the Milky Wa below Cassiopeia and explode about the sam height near th opposite horizon
16	11 38 p.m.	Seacombe, Birkenhead, Cheshire.	Much brighter than 1st mag.*	Brilliant bluish tint.	10 to 13 secs.	From altitude 40 S.E. by E. t S. by W.
16	11 40 p.m.	Bristol	Very large	?	?	Altitude 70° .....
16	About ¼ to 12 p.m.	Brading Downs, Isle of Wight.	A ball of fire, intensely brilliant.	Blue...........	5 or 6 seconds	Originated some what nearer t the horizon, N.E than it attain before explosio S.W.
27	About 10 p.m.	Bristol	Very brilliant	Deep blue ...	Quick	From a directio nearly due N.; shot in a wester direction towar the horizon.
Aug. 4	11 37 p.m.	Flimwell, Hurst Green, Sussex.	Like Pleiades, but three times as bright.	?	?	Near 30 Aquarii .
4	Midnight ...	Ibid................	Jupiter	?	Moved slowly	Centre 30° E. fro S.; altitude 47
6	10 10 p.m.	West End, Hampstead.	1st mag.*............	?	?	From 8° E. of S altitude 22° 10° W. of S altitude 10°.
6	11 21 p.m.	Manchester, Lat. 53° 29′·5, Long. 2° 15′ W.	Considerably exceeding ♀ in brilliancy.	Vivid bluish-white.	Estimated not to have exceeded 2 seconds.	Disappeared abo 2° west of t star ε Cap corni.
6	11 22 p.m.	Trafalgar Square, London.	Equalled in size the great meteor, 11.33 p.m., July 16.	?	Occupied 10 seconds in passage.	From about α C ronæ to χ Ur Majoris; near t horizon.
8	10 11 p.m.	Deal	2nd mag.*	?	Fast motion...	From γ Draconis
8	10 21 p.m.	Greenwich Observatory.	2nd mag.*	Blue............	1 to 2 seconds	Through Cassiop
8	10 31½ p.m.	Ibid................	Very small	?	1 second	μ Cygni to Sagit
8	10 31¾ p.m.	Ibid.	2nd mag.*	?	Very rapid; 2 seconds.	α Cygni to D phinus.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Spanned the heavens like rainbow-arch; prismatic momentary sparks were first emitted, but beyond the zenith a tail like that of a falling star was left, and continued visible 5 minutes.	About 140°	About E. to W., almost overhead.	The sparks in the first half of the course did not pass away immediately.	William Taylor; Miss J. W. Taylor.
Like a brilliant blue light. Very luminous tail visible 8 or 10 seconds; burst into fragments; luminous for 3 seconds after explosion.	60° to 70°	At its centre the path was inclined 18° to the horizon.	Presented a sweep of magnificent splendour through the sky.	David Walker, M.D.
?	?	E. to W.		Communicated by W. H. Wood.
A luminous track became visible several degrees before reaching the zenith. Devoid of train before this point. Broad phosphorescent wake; endured 3 minutes.	?	Passed directly overhead.	A complete view from first to last.	John A. James.
Bright track of silvery light.	?	E. to W.	One or two smaller meteors during the night in same direction.	Bristol Newspaper.
Appeared to burst			Six shooting-stars recorded from 11.15 to 12.15 p.m.	Rev. F. Howlett.
?	About 20°	Towards the left; 15° from horizontal; down.		Id.
Left a bright track, cigar-shaped.	20°	To right; 50° from vertical; down.		T. Potter.
Course bent up rather suddenly in the middle, with two maxima of brightness.	Only about 3° or 4°.	To left; 30° from horizontal; up.	Gave the impression of a path of considerable length, nearly in the line of sight.	Joseph Baxendell, Observatory, Stock St., Manchester.
The meteor in its course appeared to be extinguished, and then suddenly rekindled. Left a train of about 20°, which lasted a few seconds.	48°		The same gentlemen observed the meteor July 16th, 11.33 p.m.	T. Crumplen and J. Townsend.
No train or sparks	10°	S. preceding	Six meteors recorded, 10.11 p.m. No trains.	Herbert McLeod.
Left a small track	?	Shot upwards		W. C. Nash.
Left no track	30°	To right; 15° from horizontal; down.		Id.
Left a small track	30°	To right, 10° from vertical; down.	At Greenwich, two observers recorded 14 shooting-stars from 10 to 11 p.m.	W. C. Nash and J. Howe.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861.	h m s					
Aug. 8	10 32 5 p.m.	Cambridge Observatory.	2nd mag.*	?	Rapid	Centre 11° E. from S.; altitude 40°
8	10 34 18 p.m.	Ibid.	A bright star, 1st mag.	?	Brief	17° S. from E.; altitude 61°.
8	10 35 p.m.	Ipswich	Much brighter than any star.	?	?	Exactly N., half way between th Pole star an horizon. (Th place may b relied on.)
8	10 35 p.m.	Aylesbury (Hartwell Observatory).	A flame of light	?	Only for a moment.	In the head o sword of Perseus
8	10 40 p.m.	Birkenhead (Seacombe).	?	?	?	Due E.; altitud 17°.
8	10 45 p.m.	Aylesbury (Hartwell Observatory).	A fine shooting-star	Prismatic colours seen.	4 seconds	Near Polaris
8	10 49 34 p.m.	Cambridge Observatory.	1st mag.*	?	?	Centre 67° W. fro S.; altitude 55
8	10 50 p.m.	Birkenhead (Seacombe).	1st mag.*	?	1 second	Centre 30° E. fro S.; altitude 13
8	10 50 25 p.m.	Trafalgar Square, London.	1st mag.*	Fine blue light	Rather slow	From 3° N. Mizar to 1½ below χ Bootis.
8	10 51 p.m.	Greenwich Observatory.	A splendid meteor	?	2 to 3 seconds	Appeared near Draconis, an passed to Ar turus.
9	10 11 26 p.m.	Cambridge Observatory.	1st mag.*	?	?	Centre 3° N. fro E.; altitude 39
9	10 14 p.m.	Birkenhead (Seacombe).	1st mag.*	?	Nearly 2 secs.	Centre 45° E. fro S.; altitude 6°
9	10 27 45 p.m.	Ibid.	1st mag.*	?	1 second	Centre due S.; al tude 37°.
9	10 45 p.m.	Deal	1st mag.*	?	?	Between * and Ophiuchi.
9	10 47 p.m.	Greenwich Observatory.	Very bright	?	Momentary	Near Polaris
9	10 47 p.m.	Birkenhead (Seacombe).	1st mag.*	?	2 seconds	Centre due N.E altitude 20°.
9	10 52 45 p.m.	Ibid.	1st mag.*	?	Nearly 1 sec.	Centre 5° E. fr S.; altitude 7
9	10 57 45 p.m.	Ibid.	1st mag.*	?	2½ seconds	Centre 55° E. fr S.; altitude 2
10	0 25 a.m.	Ibid.	Shooting-stars	?	?	In W.; altitud 40°.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Left no track	?	To right, 30° from horizontal; down.	At Cambridge, three observers recorded 15 shooting-stars from 10 to 11 p.m.	Rev. J.L. Challis.
Flashed out and was immediately extinguished.	No path discernible.	......	......	Arthur Bowden.
A flash	......	Stationary	At Ipswich, one observer recorded 2 shooting-stars from 10 to 11 p.m.	Wilfred Airy.
Like a gaslight suddenly lighted and then put out.	......	......	At Aylesbury, several observers recorded 32 shooting-stars from 10 to 11 p.m.	Samuel Horton.
Fell about 2° and seemed to burst.	2°	Vertical; down	At Birkenhead, one observer recorded 7 shooting-stars.	D. Walker, M.D.
Luminous track 30° to 35°	?	E. to W.	......	Samuel Horton.
Luminous track of intermediate length, and broken up.	?	Vertical; down	......	Rev. J. L. Challis.
Tail endured 1 second ...	25°	To right, 45° from horizontal; down.	......	D. Walker, M.D.
The brilliant train of 10° remained luminous several seconds after the nucleus had disappeared.	......	......	......	T. Crumplen and J. Townsend.
Luminous track, 20° brilliant.	50°	Vertical; down	At Greenwich, two observers recorded 6 shooting-stars; very cloudy.	J. Howe.
Train 20° long	?	To right; horizontal ...	At Cambridge, three observers recorded 6 shooting-stars; cloudy.	Arthur Bowden.
Tail endured 1 second ...	25°	To left; 10° from vertical; down.	At Birkenhead, one observer recorded 32 shooting-stars (quite clear); 8 of these left tracks of light.	D. Walker, M.D.
Tail endured 1¾ second ...	25°	To right; 38° from vertical; down.		Id.
Luminous track, remained 15 seconds at least.	About 15°..	As if from Polaris	At Deal, one observer recorded 5 shooting-stars (cloudy); 3 of these left tracks of light.	Herbert McLeod.
No track left	?	Shot out from the clouds.		W. C. Nash.
Tail endured 4 seconds nearly.	20°	To right; 15° from vertical; down.	......	D. Walker, M.D.
Tail endured 1 second ...	10°	To left; 15° from vertical; down.	......	Id.
Tail endured 1½ second ...	55°	To right; 45° from vertical; down.	......	Id.
6 or 7 shooting-stars in succession; fell 10° or 12° and burst.	10° or 12°..	Almost vertical	......	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861.	h m					
Aug. 10	9 53 p.m.	Cranford Observatory.	5th mag.*	?	?	Centre E.; altitude 10°.
10		Ibid.	3rd mag.*	?	?	Centre S.S.E.; altitude 10°.
10	10 8 p.m.	Ibid.	Brilliant meteor; 1st mag.*	?	?	Between Aquila and Capricornus.
10	10 18 p.m.	Ibid.	1st mag.*; as bright as Venus.	?	?	Under Aquila
10	10 21 p.m.	Ibid.	6th mag.*	?	?	Centre E.S.E.; altitude 3°.
10	10 23 p.m.	Ibid.	3rd mag.*	?	?	Centre S.W.; 3° below α Lyræ.
10	10 23½ p.m.	Greenwich Observatory.	Small	?	Rapid; 1 second.	Passed from α Herculis towards the S.W. horizon.
10	10 24 p.m.	Cranford Observatory.	3rd mag.*	?	?	Same track as 10.23 p.m.
10	10 24 p.m.	Greenwich Observatory.	Small	?	Rapid; 1 second.	Passed from α Cygni to α Herculis.
10	10 25 p.m.	Cranford Observatory.	2 brilliant meteors.	?	?	Near Cygnus
10	10 26 p.m.	Ibid.	5th mag.*	?	?	Centre E.S.E., near horizon.
10	10 27 p.m.	Ibid.	1st mag.*	?	?	Centre E.S.E., in Pegasus.
10	10 27 p.m.	Greenwich Observatory.	2nd mag.*	Bluish	2 seconds	Passed from a few degrees above α Andromedæ to between α and β Pegasi.
10	10 28 p.m.	Cranford Observatory.	5th mag.*	?	?	Centre E.N.E.; altitude 15°.
10	10 29 p.m.	Ibid.	1st mag.*; brilliant as Venus.	?	?	From 30° to 15° altitude; centre S.S.E.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
No track left	?			W. De la Rue.
Left no track	?			Id.
Left a bright track	35°		At Greenwich, two observers recorded 33 shooting-stars from 10 to 11 p.m. At Cambridge, three observers recorded 30 shooting-stars from 10 to 11 p.m. At Cranford, one observer recorded 29 shooting-stars from 10 to 11 p.m. At Birkenhead, one observer recorded 16 shooting-stars from 10 to 11 p.m. At Deal, one observer recorded 9 shooting-stars from 10.20 to 11 p.m. At Trafalgar Square, London, two observers recorded 12 shooting-stars from 10 to 11 p.m.	Id.
Left a track	20°			Id.
Left no track	?			Id.
Left no track	?	To right; 6° from vertical; down.		Id.
Left no track	?	?		W. C. Nash.
Left no track	?	To right; 6° from vertical; down.		W. De la Rue.
Left no track	40°	To right; 25° from vertical; down.		W. C. Nash.
Left tracks	?			W. De la Rue.
Left no track	?			Id.
Left a track	?			Id.
Left a track 5° in length	15°	To right; nearly horizontal.		W. C. Nash.
Left no track	?			W. De la Rue.
A bright track marked its course throughout (15°).	15°			Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861.	h m s					
Aug. 10	10 32½ p.m.	Greenwich Observatory.	2nd mag.*	?	1 second	From γ Ursæ Majoris to the N.W. horizon.
10	10 32 32 p.m.	Cambridge Observatory.	3rd mag.*	?	Slow motion...	Centre 13° S. from W.; altitude 20°.
10	10 32 47 p.m.	Ibid.	1st mag.*	?	?	Centre same as the last.
10	10 39 p.m.	Cranford Observatory.	6th mag.*	?	?	Centre E.S.E.; altitude 4°.
10	10 40 p.m.	Trafalgar Square, London.	Very luminous meteor.	Blue light	?	¼° below χ Ursæ Majoris.
10	10 42 p.m.	Cranford Observatory.	4th mag.*	?	?	Centre S.E.; altitude 9°.
10	10 50½ p.m.	Greenwich Observatory.	3rd mag.*	?	1 second	From α Cygni to α Lyræ.
10	10 51 p.m.	Ibid.	Small	?	1 second	From α Cygni to β Delphini.
10	10 51 1 p.m.	Cambridge Observatory.	3rd mag.*	?	Rapid	Centre 26° W. from S.; altitude 46°.
10	10 56 p.m.	Trafalgar Square, London.	2nd mag.*	?	?	1° E. of α Herculi
10	10 57 20 p.m.	Deal	1st mag.*	?	?	β to α Bootis
10	10 57 30 p.m.	Ibid.	1st mag.*	?	?	α to γ Ursæ Majoris.
10	10 57 30 p.m.	Trafalgar Square, London.	Very brilliant meteor.	Blue light	Fast motion...	2° above Benetnasch to 2° above Arcturus.
10	10 58 p.m.	Greenwich Observatory.	Very bright	?	2 seconds	From α Pegasi. Passed Delphinus to α Aquilæ.
10	10 59 p.m.	Birkenhead (Seacombe).	1st mag.*	?	Moved 1 sec...	Centre 26° E. from S.; altitude 30°.
10	From 10 to 11 p.m.	Haverhill	Shooting-stars			In all quarters
10	From 11 to 11½ p.m.	Ibid.	Shooting-stars			In all quarters o the sky.
10	11 45 p.m.	Birkenhead (Seacombe).	?	?	?	?
11	1 3 a.m.	Weston-super-Mare.	Mars	Like the electric light.	?	Centre 40° W. fro N.; altitude 18°
11	8 40 p.m.	Hawkhurst, Kent	1st mag.*	?	Rapid	Centre 22° W. fro S.; altitude 39°
11	8 45 p.m.	Trafalgar Square, London.	Grand and luminous, even in strong twilight.	?	Rather slow...	15° below Merak.
11	8 53 p.m.	Hawkhurst	Jupiter	?	Slow motion...	Centre 22° W. fro S.; altitude 37

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Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Left a small track	?	?		W. C. Nash.
Left no track	?	Vertical; down		Rev. J. L. Challis.
Left a track	?	To left; 45° from vertical; down.		Id.
Left no track	?	→		W. De la Rue.
Marked track 8° in length	?	?		T. Crumplen and J. Townsend.
Left no track	?	→		W. De la Rue.
Left no track	(25°)	To right; 30° from vertical; down.		W. C. Nash.
Left no track	(30°)	Vertical; down		J. Howe.
Left no track	?	To left; 30° from vertical; down.		Rev. J. L. Challis.
Left no track	?	Stationary		T. Crumplen and J. Townsend.
Left a track	20°			Herbert McLeod.
Left a track	15°			Id.
Left a track 20° long				T. Crumplen and J. Townsend.
Beautiful track; 30° in length.	(45°)	To right; horizontal		J. Howe.
Track endured 1 second	20°	To left; 37° from horizontal; down.		D. Walker, M.D.
		Mostly divergent from Cassiopeia.	Two observers delineated the courses of 70 meteors in the hour.	W. W. Boreham and J. Hobler.
		Diverging from Cassiopeia.	Two observers delineated 45 meteors.	Id.
This star curved considerably in its path before it burst.	?	?		D. Walker, M.D.
Track of 3° 15′ broad; lasted 4 seconds.	10°	Inclined westward 30° to the vertical.	From 1.25 a.m. to 1.40 a.m., meteors fell too fast to be registered.	W. H. Wood.
No train or sparks	10°	To right; 30° from vertical; down.	Strong twilight	A. S. Herschel.
?	?		Too cloudy for better observation.	T. Crumplen and J. Townsend.
Bright enduring track	20°	To left; 30° from vertical; down.		A. S. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861.	h m s					
Aug. 11	9 27 p.m.	Flimwell, Hurst Green, Sussex.	Jupiter.............	?	?	Centre 30° S. from E.; altitude 31°.
11	9 27 p.m.	Ibid...............	Jupiter.............	?	Very slow ...	From near ι Cygni to η Pegasi.
11	9 30 p.m.	Hawkhurst, Kent	Jupiter.............	?	?	Centre 30° S. from E.; altitude 31°.
11	10 0 p.m.	Flimwell, Hurst Green, Sussex.	4th mag.*	?	?	From ½ (γ Equulei and γ Delphini) to Equilat. with (θ and ι Delphini).
11	10 15 p.m.	Ibid...............	Jupiter.............	?	Moderate speed.	Down; W. margin of E. branch of Milky Way. From ½ (δ λ) Aquilæ to φ Sagittarii.
11	10 17 4 p.m.	Hawkhurst, Kent	Venus, or somewhat larger in first two-thirds of course.	Bright bluish in first two-thirds, then dull red.	2 seconds; slow motion.	Down the Milky Way from Aquila to Sagittarius.
11	10 20¼ p.m.	Ipswich	Vivid meteor	It was a palish meteor, not a brilliant white one.	Moved very slowly; 2½ seconds.	In a line through δ Ursæ Majoris, just above β Ursæ Majoris.
11	10 22 p.m.	Hawkhurst, Kent	Brighter than Venus. It cast a shadow.	Pure white ...	1⅓ or 1½ sec.	Centre 33° N. from E.; altitude 16°.
11	10 27 p.m.	Ipswich	Very bright	White	....	Ceased at γ Pegasi.
11	10 28 p.m.	Flimwell, Hurst Green, Sussex.	Jupiter.............	?	Rapid	....
11	10 37 p.m.	Weston-super-Mare.	2nd mag.*	?	Rapid	Centre 72° E. from N.; altitude 19°.
11	10 37 p.m.	Ibid.	1st mag.*	?	Rapid	Centre 29° W. from N.; altitude 10°.
11	10 37 p.m.	Ibid.	2nd mag.*	?	Slow motion...	Centre 43° E. from N.; altitude 24°.
11	10 47 59 p.m.	Hawkhurst, Kent	2nd mag.*	?	Very slow motion.	Centre 15° S. from E.; altitude 35°.
11	10 11 p.m.	Haverhill	Shooting-stars......	....	....	In all parts of the sky.
11	11 0 p.m.	Weston-super-Mare.	3rd mag.*	?	?	Centre 3° S. from W.; altitude 26°.
11	11 2 p.m.	Ibid.	4th mag.*	?	?	Centre 3° S. from W.; altitude 26°.
11	11 8 p.m.	Hawkhurst, Kent	1st mag.*	?	Very fast	Centre in zenith ...
11	11 20 p.m.	Flimwell, Hurst Green, Sussex.	3rd mag.*	?	Rapid	....
11	11 20 p.m.	Ibid.	3rd mag.*	?	Rapid	....
11	11 20½ p.m.	Ibid.	2nd mag.*	?	Rapid	....

Appearance ; Train, if any, and its Duration.	Length of Path.	Direction ; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
	20°	To right ; 45° from horizontal ; down.		Rev. F. Howlett.
Left a track	(30°)			Id.
?	20°	To right ; 45° from horizontal ; down.		A. S. Herschel.
?	5°	To right ; horizontal ...	Path was arched convex to Delphinus.	Rev. F. Howlett.
	28°	Vertical ; down		Id.
Straight track left in 1st two-thirds (the rest barren) ; remained 4 seconds.	25°	To right ; 15° from vertical ; down.		A. S. Herschel.
It was a large pear-shaped meteor.	10°			W. Airy.
Left a white bright track throughout, lasting 7 seconds in the middle.	Not more than 7° or 8°.	To right ; 15° from vertical ; down.	Brightest seen this night.	A. S. Herschel.
Left a good tail, which lasted 5 or 6 seconds.	A short run	To right ; 40° from horizontal ; down.		W. Airy.
Brilliant white track				Rev. F. Howlett.
No train or sparks	5°	To right ; 30° from vertical ; down.	Three meteors fell simultaneously.	W. H. Wood.
No train or sparks	5°	?		Id.
No train or sparks	15°	Vertical ; down		Id.
Slower and redder at last ; turning to left, and tail ceasing.	5°	To right ; 30° from vertical ; down.		A. S. Herschel.
		From Cassiopeia	Two observers counted 46 meteors in one hour ; clear sky.	W. W. Borcham and J. Hobler.
Left a track	5° or 6° ...	To left ; 30° from horizontal ; down.	Two meteors pursued the same apparent path.	W. H. Wood.
Left a track	5° or 6° ...	To left ; 30° from horizontal ; down.		Id.
Left a long track visible 5 seconds.	20°	Vertical ; towards 45 W. from S.		A. S. Herschel.
?		From θ Cassiopeiæ to 16 Cap. Medusæ.		Rev. F. Howlett.
?	?	?		Id.
		From ½ (α π) Andromedæ to ½ (β, 7) Cephei.		Id.

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Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861.	h m s					
Aug. 11	11 23 p.m.	Hawkhurst, Kent	2nd mag.*	?	Slow	Centre 30° N. from E.; altitude 33°. Good observation.
11	11 23 10 p.m.	Ibid.	4th mag.*	?	?	Centre due E.; altitude 40°.
11	11 23 20 p.m.	Ibid.	2nd mag.*	?	?	Centre 23° S. from E.; altitude 30°.
11	11 38 p.m.	Weston-super-Mare.	1st mag.*	?	Exceedingly swift.	Centre 29° S. from E.; altitude 26°.
11	11 41 10 p.m.	Hawkhurst, Kent	2nd mag.*	White	Momentary	From ζ to ½ (β γ) Lyræ.
12	0 1 20 a.m.	Ibid.	2nd mag.*	Brilliant white	Very slow motion.	Centre 40° W. from S.; altitude 36°.
12	0 31 20 a.m.	Ibid.	1st mag.*	Brilliant white	Slow motion	Centre 7° E. from N.; altitude 45°.
12	0 52 5 a.m.	Ibid.	3rd mag.*	?	?	Centre 23° E. from N.; altitude 57°.
12	1 9 50 a.m.	Ibid.	1st mag.*	?	Rapid	Near β Cephei. Centre 27° W. from N.; altitude 73°.
12	1 18 20 a.m.	Ibid.	3rd mag.*	?	?	γ Cygni to ι Cygni. Centre 40° S. from W.; altitude 65½°.
12	1 31½ a.m.	Ibid.	4th mag.*	?	Moderate speed.	…………
12	1 31½ a.m.	Ibid.	4th mag.*	?	Moderate speed.	E. from S. 38°; altitude 80°.
12	1 31½ a.m.	Ibid.	2nd mag.*	?	Moderate speed.	E. from S. 117°; altitude 52°.
12	1 31½ a.m.	Ibid.	2nd mag.*	?	Moderate speed.	E. from S. 45°; altitude 44°.
12	2 6 a.m.	Ibid.	1st mag.*	?	Fast motion	Out of γ Pegasi. Centre due S.; altitude 56°.
12	2 6 2 a.m.	Ibid.	4th mag.*	?	?	Just below the last
12	2 14 30 a.m.	Ibid.	2nd mag.*	?	Rapid	Centre 8° E. from S.; altitude 27°.
12	2 14 40 a.m.	Ibid.	Twice the width of the moon; irregular circle.	White	Rapid	Centre 3° or 4° below the last.
Sept. 6	8 0 p.m. (approximate time).	Blackheath	=2nd mag.*	Bluish white	1 to 2 secs.	From a point between Polaris and α Draconis to ο Ursæ Majoris.
26	10 0 p.m.	Greenwich	3rd mag.	?	?	Appeared ½ (ι and ζ) Ursæ Majoris

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Left a bright track visible some seconds.	8°	To right; 20° to 25° from vertical; down.	A slow meteor with enduring track.	A. S. Herschel.
No track or sparks; straight course.	25°	To left; 38° from horizontal; up.	Remarkable for direction, length, and smallness.	Id.
No track or sparks	10°	To right; 30° from vertical; down.	Ordinary appearance	Id.
Bright track throughout, 15′ broad; enduring 2 seconds.	15° or 16°	To right; 15° from vertical; down.		W. H. Wood.
Bright white track throughout; endured 3 seconds.	7°			A. S. Herschel.
No sparks; no track	10°	To left; 35° from vertical; down. Curved to left at last.		Id.
Bright track; endured 3 seconds at centre.		To left; 35° from vertical; down.		Id.
No track; the light appeared to sparkle.	?	?		Id.
Track brightened up when nucleus had vanished; visible 3 seconds.	10°	To left; horizontal		Id.
Good observation of track, which brightened up after meteor was flown.	15°	To right; 35° from vertical; down.		Id.
	15°			Id.
?	15°	30° from horizontal	Three meteors to left; downwards; appeared together.	Id.
?	3°	60° from horizontal		Id.
?	10°	30° from horizontal		Id.
Left a track	15°	To right; 15° from horizontal; down.		Id.
?	15°	Parallel to last		Id.
Left no track	12°	To right; 35° from vertical; down.		Id.
Nebulous; left no track	12°	Parallel to the last	A singular brush. Flew crooked, 10 seconds after the last, and like its ghost (cloudless sky, calm air).	Id.
None	25°			W. C. Nash.
Slight train	5°	S., S. following	Cloudy night	J. MacDonald.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861.	h m					
Sept. 26	10 0 p.m.	Blackheath	= 1st mag.*.........	White	2 seconds......	Appeared a fe degrees abo Ursa Major, passing betwe the stars α a β, disappeari behind a clo at about 10° 15° from th constellation.
29	8 40 p.m.	Ibid.	= 3rd mag.*	Blue	1 second	From β Delphi across α Aquil to δ Aquilæ.
29	8 52 p.m.	Ibid.	= 1st mag.*.........	Blue	1 to 2 seconds	Moved in a sout erly direction few degrees below the Pleiades.
Oct. 2	8 40 p.m.	Greenwich Park	Faint	....	Momentary ...	From ι Persei ζ Aurigæ.
4	9 30 p.m.	Greenwich	= twice the size of a 1st mag.*	Pale green ...	3 seconds......	From about t centre of Cam lopardus; pass diagonally acr Ursa Major fro α to γ, and di appeared a fe degrees bel the latter star.
4	9 48 p.m.	Ibid.	= 2nd mag.*	Blue	1 second	From η across θ Draconis.
4	10 29 p.m.	Ibid.	= 3rd mag.*	....	1 second	From the Pleia to γ Tauri.
4	10 36 p.m.	Ibid.	= 1st mag.*.........	Blue	1 to 2 seconds	Across Capella about 20° in northerly direction.
4	10 40 p.m.	Ibid.	= 2nd mag.*	Blue	1 second	From γ Pegasi, halfway to Pegasi.
4	10 46 p.m.	Ibid.	Small faint meteor	....	1 second	Passed rapidly fr ι Persei to Arietis.
9	8 50 p.m.	Ibid.	= 3rd mag.*	Bluish white...	1 second	From γ Andromedæ to κ Persei.
9	9 20 p.m.	Ibid.	= 2nd mag.*	White	1 second	From μ Andromedæ to δ Cassiopeiæ.
9	9 31 p.m.	Ibid.	= 3rd mag.*	Blue	1 second	From β Cygni ζ Aquilæ.
9	9 50 p.m.	Harrogate	?	?	?	30° from zenith N.W.
10	8 42 p.m.	Greenwich	= 2nd mag.*	Blue	....	Fell from zeni towards the S.
10	8 43 p.m.	Ibid.	= 3rd mag.*	White	1 second	From γ to β C phei.
10	10 7 p.m.	Ibid.	= 2nd mag.*	Bluish white...	1 second	Across Cassiop to γ Cephei.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Slight train			Rather cloudy	J. MacDonald.
None	22°			W. C. Nash.
Small train	10°			Id.
None	10° to 15°			Id.
Brilliant train	About 45°		A very brilliant meteor.	Id.
None	7°			Id.
None	11°	Almost perpendicular		Id.
Train	20°	S. to N.; horizontally		Id.
None	About 10°			Id.
None	29°			Id.
None	17°			Id.
	22°			Id.
	15°			Id.
Many shooting-stars	?	?		J. Coupland.
None	8°	Perpendicular		J. MacDonald.
None	12°			W. C. Nash.
Small train	20°			Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861.	h m					
Oct. 10	10 16 p.m.	Greenwich	=2nd mag.*	Blue	1 second	Across α Lyr towards N.V horizon.
10	10 20 p.m.	Ibid.	=2nd mag.*	White	1 to 2 seconds	From ξ to δ Cygn
11	9 25 p.m.	Blackheath	=2nd mag.*	White		Fell from a fe degrees abo the Pleiades passing throu them; disappearing abou 15° below.
11	9 30 p.m.	Greenwich	=1st mag.*		1 second	Passed rapidly fro ι Aurigæ to Ceti.
11	9 30 p.m.	Blackheath	Small	Bluish white		Shot up from t southern horizon.
11	9 42 p.m.	Ibid.	Small		1 second	Passing from E. W. a few grees above Pleiades.
14	8 20 p.m.	Greenwich	=2nd mag.*	Blue	1 second	Passed from n τ Herculis aen μ Draconis.
14	10 26 p.m.	Ibid.	=1st mag.*	Bluish white	1 to 2 seconds	From δ Arietis γ Trianguli.
22	10 21 p.m.	Ibid.	=1st mag.*		2 to 3 seconds	Across α Geminorum.
23	7 28 p.m.	Ibid.	=2nd mag.*	Blue	1 second	From Equuleus wards the horizon.
23	7 28 p.m.	Ibid.	=2nd mag.*	Bluish white	1 second	From α Equulei β Aquilæ.
24	8 59 p.m.	Ibid.	=3rd mag.*	White	1 second	Passed rapidly fr δ Cygni to Lyræ.
Nov. 2	10 47 p.m.	Birkenhead	Very bright		8 or 9 seconds	From centre Pleiades to of Aldebaran.
6	7 0 p.m.	Greenwich	=1st mag.*			Fell from the zen towards the for about 12°
7	8 45 p.m.	Blackheath	=2nd mag.*		2 seconds	From the nei bourhood of pella, and pas to γ Ursæ joris.
7	8 49 p.m.	Ibid.	Small		2 seconds	From the nei bourhood of pella, in the rection of Al baran for ab 5°.

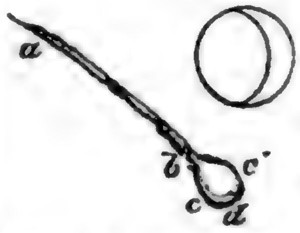
Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
None				W. C. Nash.
Small train	15°			Id.
Small train	20°			J. MacDonald.
Small train	40°			W. C. Nash.
None	8°			J. MacDonald.
None	7°	Horizontal		Id.
Train	20°			W. C. Nash.
Train	15°		Moon shining brightly.	Id.
Bright train	30°	S. to N.		Id.
Faint train	15°		The next meteor followed this one at an interval of a few seconds, springing from nearly the same place.	Id.
Train	20°		Cloudy after this time for the remainder of the evening.	Id.
No train	15°			Id.
Left a luminous tail for about 3 seconds and burst, leaving the fragments luminous for a short period.				D. Walker.
	12°			J. MacDonald.
None		Inclined upwards		Id.
	5°			Id.

UNIVERSITY OF CALIFORNIA

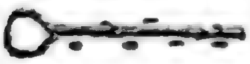
Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861.	h m					
Nov. 8	8 5 p.m.	Exeter	Larger than a Roman candle-ball.	....	....	S.S.E., over Torbay or mouth of the Exe. From altitude 30° or 40° to very near the earth.
10	9 22 p.m.	Greenwich	=2nd mag.*	....	Momentary ...	From the direction of Camelopardus, passed midway between Polaris and α Draconis.
10	10 34 p.m.	Ibid.	=3rd mag.*	Blue	1 second	From ι Tauri to a point a little above η Geminorum.
10	10 38 p.m.	Ibid.	Faint meteor	Blue	1 second	From between ζ Tauri and η Geminorum to θ Aurigæ.
10	11 1 p.m.	Ibid.	=2nd mag.*	Blue	2 seconds......	Passed from γ Geminorum in a westerly direction, across the upper part of Orion.
11	9 0 p.m.	Ibid.	Small	Blue	1 second	Fell from a few degrees W. of Ursa Major to about 10° from Aldebaran.
11	10 36 p.m.	Ibid.	=2nd mag.*	Blue	1 to 2 seconds	From the Lynx constellation; disappeared a few degrees below Polaris.
11	10 52 p.m.	Ibid.	=2nd mag.*	Bluish white...	1 second	From ε Eridani towards the S. horizon.
12	5 45 p.m.	Hay, S. Wales...	Pear-shaped; 30′ by 15′ at first, but 20′ by 10′ at middle of its course.	A fine blue ...	About 5 secs...	From near the body of Cygnus. Altitude 60° or 70°, down W. branch of Galaxy, between Altasi and Ophiuchus, to 10° above the horizon, W.S.W.
12	5 45 p.m.	Weston-super-Mare.	Nearly the size of the moon.	?	3 seconds......	From 3° above α Herculis to near the S.W. by S. horizon.
12	5 45 p.m.	Southern Hay, Exeter.	Larger than any Roman candle-ball.	Deep blue ...	?	From the tail of the Great Bear.
12	5 48 p.m.	Barlaston, Stone	Elongated as long as the moon's diameter.	Greenish white.	Fell slower than a shooting-star.	From 20° W. of S. altitude 40° to 40° W. of S. altitude 8° or 9°.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Burst into a bright light when first seen; left here a transitory track; dropped to objects on the horizon fading away; skittle-shaped.	......	Fell vertical	Another light was seen in the W. an hour later.	G. A. Lance.
Small train	10°	......	......	W. C. Nash.
Train	17°	......	......	Id.
......	15°	......	......	Id.
Train	25°	Horizontally, E. to W.	......	Id.
......	......	......	......	J. MacDonald.
Train	20°	......	......	W. C. Nash.
Train	10° to 15°	Almost perpendicular	......	Id.
Ruddy sparks emitted behind. Pursued by a long pale streak of light.	(60° to 65°)	To right; from 20° to 8° or 10° from vertical; at last down.	Flashed overhead like sudden moonlight, but did not continue so bright as it advanced. Moon ten days old.	Rev. T. W. Webb.
Threw strong moving shadows. Left a bright track 50°, which lasted 10 seconds.	50°	Inclined	Probably started from the head of Draco.	W. H. Wood.
Appeared to burst	?	Longitudinally westward.	......	A. J. Cumming.
Largest and brightest at the head, tapering to a reddish tail.	A short course.	Inclined downwards in a slightly curved line, not straight.	Cloudy	G. Wedgwood.

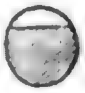
Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861. Nov. 12	h m 5 49 p.m.	Manchester (12 miles S.E.).	$ab=60'$; $bd=13'$; $cc'=10'$.	Nucleus yellowish flame, conical part brilliant blue.	3½ seconds ...	From S.S.E. altitude 35°; to nearly S. altitude 8°.
12	5 50 p.m.	Bristol	Brighter than the moon.	Vivid blue ...	?	Very nearly overhead.
12	5 50 p.m.	Stone, near Aylesbury.	Oval shape, nearly = to the moon.	Pale brilliant blue.	About 6 secs.	First seen a littl N. of Pole-sta (γ Cephei), t 15° above horizon, W.S.W.
12	6 3 p.m. Local time.	Oxwich, South Wales.	As large as a cricket-ball.	Steel-blue ...	?	From 6° or 7° S and W. of Pleiades to same height at th opposite side (the heavens. Started 3° S. (Pennard Castl from Oxwich Rectory.
15	10 14 p.m.	Greenwich	=Venus	A greenish tint predominated.	4 or 5 seconds	From the zenith i a northerly d rection. Owin to the dense haz the path of th meteor amon the stars coul not be traced.
15	10 15 p.m.	Shooter's Hill, Woolwich.	Aldebaran or Mars for half its course, then flaming; diameter 5′; last 3°=Mars.	Mars for half its course, dull; then steel-blue, brilliant. Last 3°= Mars, and faded away.	3⅓ seconds by chronometer.	From 1 Hev. C meleopardi t β Ursæ Minori Began to flar at the Pole-star
15	About 10 15 p.m.	Styall, near Manchester.	Oval nucleus 8′ long	Bluish	3 seconds	From S.E. by altitude 42°; t S.E. by S. alt tude 18°: bur with sparks (?)
19	5 30 p.m.	Sherwood, 7 miles N.W. of Exeter.	Much larger than any of the fixed stars.	Blue, bursting like a Roman candle.	7 or 10 seconds	....

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Figure sharply defined; very few sparks or breaks; no permanent tail left; no disruption at disappearance.	25°	To right; from 43° to 61° to the horizontal; down.	....  Figure of the meteor compared with the moon.	R. P. Greg.
Left a track of golden light.	?	As nearly as possible S.S.W.	....	Rev. W. M. Burch.
No sparks or tail; burst into large fragments; much scattered; no noise heard.	(90°)	Inclined	Very foggy. Flashed an intense light, as if it broke out from behind a cloud before it was seen; loose clouds.	William Penn.
Roman candle-ball, with red sparks and fire; tail 8° or 10°, tapering into detached sparks.	(130° to 140°.)	Mounted as it approached, moving apparently level with the sea.	Appeared level with the eye, and stationary at first; very bright.	S. G. L.
Brilliant train throughout the whole of its course. About 1 second before the meteor disappeared, it threw off a small luminous fragment apparently 1/8th the size of the whole body, which suddenly disappeared after travelling 1° or 2°. No noise was heard.	50°	S. to N.	An exceedingly hazy night. Moon and one or two principal stars seen. A fine lunar halo.	W. C. Nash.
No track left; when nucleus flamed blue, red sparks were emitted *all round* = ½ diameter of moon.	40°	Almost vertical; down..	The flaming nucleus irregular in figure, but not elongated; hazy sky; full moon; halo. (No other meteor was visible in the heavens from 9½ to 11 p.m.)	A. S. Herschel.
Left a streak	....	To right; 35° from vertical; down.	The position carefully taken from memory.	R. P. Greg.
....	....	From γ Ursæ Majoris...	The meteor appeared to drop between us and the opposite hill; we felt certain it dropped in the valley.	Arthur Cumming.

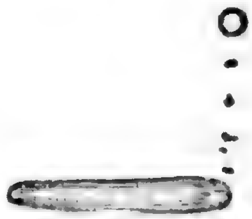
Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861. Nov. 19	h m s 9 15 to 9 35 p.m.	Ipswich	Large as the moon, but very much brighter.	A bright stream of fire.	It did not move very fast, but like a spent rocket; like a Roman candle-ball.	Approached fro the S.E., bursting into 3 piec when almost overhead.
19	Between 9 & 10 p.m.	Norwich	A bright body as large as the moon.	?	?	Burst into 3 part nearly overhea
19	9 35 p.m.	Whitstable	A splendid meteor..	?	?	The grand explosion took plac close underneat the Great Bear.
19	9 35 p.m.	Guestling Hill...	Half diameter of the moon.	White	?	Rose from a ban of clouds 30° E from S.; disappeared a littl left of Wittersham, 20° E from N. Passe 4° or 5° unde the moon, whic had altitude about 40°.
19	Disappeared 9 38 23 p.m.	Greenwich Observatory.	One-half the diameter of the moon.	?	Nearly 10 secs.	Appeared betwee γ Orionis an Aldebaran (fro behind great dome of equat real). Passed 6 or 8° below Pollux, and di appeared 15° further N.
19	9 40 p.m.	Woodford	At first stationary; =Venus. When under the moon =¼ of moon's diameter.	Pale green when underneath the moon, then blue.	At least 10 seconds.	At first stationa for 2 second at a point i Cetus. Advanced nort ward under t moon at half i altitude, an finally disappeared witho noise.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Threw strong moving shadows. Broke into 3 pieces or streams of fire, which soon disappeared; as large as a man's fist.	....	S.E. towards the N......	About 80 or 90 seconds after the explosion, three distinct reports like heavy ordnance or distant thunder were audible.	Mr. Felgate; G. Webb; G. Pulham; Robert Bixby; Frank Mayhew; John Steel; *Charles Lawrence* (communicated by G. Biddell).
Burst into 3 parts; one or two appeared to fall, and the other seemed to rise.	?	From S. by W. towards N.E.	A full minute afterwards heard a loud report.	Rev. G. Gilbert.
Exploded with an appearance of 6 to 8 balls of fire.	....	S.S.W. to N.N.E., horizontally across the sky.	....	James Pearce.
....  The train of prismatic colours; fragments ruddy brown. Threw out fragments, and parted into two before reaching and in passing under the moon. When disappearing, three ruddy brown fragments were the last things seen.	120°.........	Horizontal	....	Messrs. James Rock and C. Savery, M.R.C.S.
Magnificent meteor; carried a splendid coloured train with sparks, and at last broke into 3 or 4 and vanished.	?	Inclined downwards 15° or 20° from horizontal.	....	W. T. Lynn.
Blazed forth suddenly near the moon like oxyhydrogen lime-light; then developed a fiery tail, nucleus becoming blue. Broke into 3 or 4, like beads on a string, just before disappearance.	?	Horizontal	....	John Hill.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861. Nov.19	h m 9 40 p.m.	Godstone, Surrey	?	?	?	First seen S. of some distan before it came the moon. E ploded plain, N
19	9 40 p.m.	Tunbridge	One-third the size of full moon.	White with a bluish shade.	From 10 to 15 seconds.	First seen as ov Langley Poi Pevensea H bour. Passed n more than below the moo
19	9 45 p.m.	Heavitree, Exeter	Light very bright and steady; occasionally thicker in some parts than others; like an unusually large star.	Bright white...	Moving by no means quickly in a straight line.	Came out from t sky, and disa peared witho noise; unifo altitude of 1 to 20°.
19	9 45 p.m.	North Foreland	A body nearly equalling the moon, but far brighter.	....	Moved slowly, continuing in sight 10 to 12 secs.	From 60° altitu S.E.; passed E. of the zen towards true burst N. by altitude 12° 15°.
19	?	Dover	Much larger and brighter than Roman candle-ball.	Ball of yellow fire, pure and pale.	?	At the Tan Ya Stembrook, Dover, the meteor dis peared behi the Castle Hil
19	?	Wrotham Hill, Kent.	Threw a great light on the opposite side from the moon.	?	?	From the S.S part of the h vens; trave many miles fore it came the moon. Passed under moon and lost to vi behind cha hills.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	?	?	Companion of observer thought that his coat was on fire. Observer thought it lightened.	W. Blackstone.
 Only the top of the moon was visible, the lower part being outshone by the meteor. When the explosion took place, 7 balls of fire about the size of an orange formed themselves *into a sort of tail.*				
Threw shadows half as deep as those of the moon; rocket-like tail 8 or 10 feet long. Divided into two parts on passing the moon; burst into 10 or 12 fragments, which were red.	....	Nearly due S. to N.; horizontal; altitude 30°.	Brightness did not vary. A hissing noise was heard as it passed.	W. Mitchell; John Harmer (communicated by C. V. Walker).
The appearance was that of a light running along an outstretched line, like the light of a rocket.	About $\frac{1}{6}$th of the circle of the horizon (=60°).	Direction from S.W. to N.E.; horizontal.	Appeared to drop something as it went along.	R. T. Abraham.
Carried a tail 3° long; violet at the head; tapering to a flickering point; flame coloured; 2 or 3 seconds before bursting a globular body separated from the head to halfway along the tail, and there continued. Exploded into many fragments, which fell some distance.	Full 70° ...	Curving towards the earth.	About two minutes after extinction, a short dull but loud report was heard; distinctly but closely double.	James Chapman.
Shadows in the street; moved rapidly.	....	The meteor was observed to explode near Maldon, in Essex.	....	Edmund Brown.
After passing the moon, began to vomit fire of the most brilliant hues.	....	?	The air smelt of sulphur	James Douse.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861.	h m					
Nov.19	?	Wrotham Hill, Kent.	Four times the size of one of the planets; threw shadows on the fields.	Brilliant white	?	Appeared S.S. passed 4½ wid underneath t moon. Burst wi bright colo near the N.
24	7 40 p.m.	Broxbourne	Somewhat larger than Sirius.	White with bluish tinge.	1½ second	Appeared 5° W. β Cygni; disa peared 4° E. α Aquilæ on t equator.
24	8 10 p.m.	Weston-super-Mare.	= Sirius	Brilliant blue.	2 seconds	Appeared in Ple des; disappear near α Ceti.
24	10 2 p.m.	Greenwich	= 2nd mag.*	Bluish white	1 second	Started near Orionis; pass towards the h rizon through Orion, and d appeared a litt to the left of Orionis.
26	5 42 p.m.	Ibid.	Small	Bluish white	1 second	Passed through t Pleiades in t direction of A debaran.
27	9 32 p.m.	Greenwich Observatory.	= 2nd mag.*	White	1 second	From γ Geminoru to a point b tween α and Orionis.
27	10 6 p.m.	Ibid.	= 2nd mag.*	Blue	1 to 2 seconds	Shot between α a β Geminorum.
27	10 16 p.m.	Ibid.	= 1st mag.*	Bluish white		Moved below U Major towar N. horizon.
30	8 54 p.m.	Ibid.	= 5th mag.*	Blue	0·7 second	Nearly in the pla of the meridia and about 2 from the horizo
30	11 11 p.m.	Greenwich	Small but bright	Blue	About half a second.	α Orionis to ι O onis.
Dec. 1	1 50 p.m.	Wakefield	Very brilliant	Bluish white		From overhead eastward; disa peared behind railway emban ment.
1	8 26½ p.m.	London	= α Lyræ	α Lyræ	Moderate speed.	Appeared near Draconis.
1	8 37 p.m.	Greenwich	= 2nd mag.*	Blue	2 seconds	From λ Lyræ within 10° of t W. horizon.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Blood-red; tail like a Roman sword. 	?	Horizontal when underneath the moon.	Clear sky; no smell of sulphur.	James Douse.
Train about 9° in length...	?			H. S. Eaton.
No tail	?	Inclined	Many came from this locality for several evenings. This was the largest and brightest.	W. H. Wood.
Train	15°			W. C. Nash.
None	8°		Rather cloudy	J. MacDonald.
Train	18°		A fine bright night	W. C. Nash.
Train	5° to 7°	Inclined path, S. to N.	A fine bright night	Id.
Train		Inclined towards N.	A fine bright night	Id.
No train; disappeared suddenly.	4°	Towards the W., at an angle of 45° to the horizon.	It was very small and rapid.	H. C. Criswick.
None	10°		Rapid motion	W. C. Nash.
Left a long train behind it; no explosion was seen.		Nearly vertical	The sun shining at the time.	
Left a short tail	20°	Directly from Polaris	Remainder of flight intercepted by houses.	Herbert McLeod.
Train of some length	20°			W. C. Nash.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861.	h m					
Dec. 1	8 50 p.m.	Greenwich	= 2nd mag.*	....	1 second about.	Fell perpendicularly from a point a little above and to th W. of Ursa Major.
1	9 8 p.m.	Blackheath Hill, Greenwich.	Size of Sirius	The colour of the unclouded moon.	1·5 second ...	From between th Pleiades and Algol; nearer the latter.
1	9 14 p.m.	Walthamstow ...	Somewhat smaller than Polaris.	Pale yellow ...	3 seconds ...	From ½ (Aldebara and α Orionis to 8° W. o Castor.
1	9 15 p.m.	Weston-super-Mare.	Diameter 2′	....	Very slow; 5 seconds; speed slackening steadily, until almost stationary.	Appeared betwee γ Orionis an α Orionis, an burst 4° abov κ Orionis.
2	9 45 p.m.	Barlaston, near Stone, Salop.	Larger than Venus, but not so bright.	Greener than the greenest rays of stars.	Rapid motion..	From altitude 45 due E.
3	5 20 p.m.	Blackheath	= 1st mag.*	Blue	Less than 1 second.	From direction Cassiopeia to Pegasi.
4	2 5 a.m.	Birkenhead (Seacombe).	Bright meteor	?	5 seconds......	From centre quadrate stars Ursa Major within 10° of th horizon.
7	At night ...	Preston	Large meteor	?	?	? ....
8	8 15 p.m.	Lancaster.........	Almost as large as the moon.	?	?	Burst; altitude 2 or 30° a little of N.W.
8	8 15 p.m. exactly.	St. Bees, 1½ mile inland.	Ball of fire 5 inches in diameter.	?	3 seconds in perfect state; 6 seconds in all.	....
8	About 8½ p.m.	Bridlington Quay.	As large as the moon.	....	?	? ....

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	....	....	J. MacDonald.
There was no train; but after having travelled about 3° or 4°, it broke into five portions, three of the portions being as large and bright as the meteor when first seen.	7°	It took a course due S.; the path, which was short, appeared to be a horizontal line.	This meteor, although not very large, was exceedingly bright; after breaking up, it was visible for about 0·5 sec.; no noise was heard.	H. C. Criswick.
Light unsteady, brightening, and then diminishing.	....	A serpentine course ...	....	H. S. Eaton.
Grew brighter and pear-shaped in falling; train 10°; half disappeared in the flight; fragments proceeded as streamers after bursting; 5°, diverging.	....	....	....	W. H. Wood.
Grew to size of Venus; clear drop of green light disappearing suddenly at maximum, with a red fragment.	20°	Fell vertical	....	
Train	....	....	....	W. C. Nash.
Fell gently	....	Perpendicular	....	D. Walker, M.D.
Similar to that of the night following.	?	?	....	Communicated by R. P. Greg.
?	?	From the Pole-star downwards to due W. From overhead downwards, N.W.	Hissing sound like quenching iron during the passage of the meteor; two minutes later, a sound like the discharge of a heavy gun.	Correspondent, 'Lancaster Guardian.'
In the last half of its course shot out a thousand most brilliant stars; diminished in size, and vanished at last, leaving a cloud about it.	?	Appeared to descend into the Irish Channel, between St. Bees and the Isle of Man.	....	Isaac Sparks.
Left a blaze of light behind.	?	?	?	S., Correspondent, 'Manchester Guardian.'

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861.	h m					
Dec. 8	8 15 p.m.	Hull	Size varied; light exceeded that of the moon.	White, then blue.	2 seconds......	From 10° to 15° above the moon whence moved perpendicularly in a curved line towards the earth westward to 20° above the horizon.
8	8 15 p.m.	York (Holgate)...	Half the size of a cricket-ball.	....	....	....
8	8 15 p.m.	Southport	Almost as large as the moon; bright as noon-day.	Blue light; colour pale blue.	?	From about the Pole-star to altitude 25° or 30° a little W. of N.W.
8	8 15 p.m.	Manchester	Longest diameter equal that of the moon.	Pale blue	?	From a point near the Pole-star to the horizon, westerly.
8	8 15 p.m.	Liverpool.........	Like the moon as seen at the time.	....	Rapid flight; 3 seconds.	....
8	8 15 p.m.	Ibid.	....	Blue light, like lightning.	....	....
8	8 16 p.m.	Prestwich, Manchester.	?	?	?	? ....
8	8 18 p.m.	Dundee	One-third diameter of the moon.	Bright white, like molten metal.	10 or 15 secs.	About the altitude of Sirius or Orionis; above the horizon at the time.
8	8 20 p.m.	St. Bees, Cumberland; 3 miles inland.	Brilliant meteor or shooting-star.	?	?	From altitude 45° due S. downwards.
8	8 20 p.m.	Castletown, Isle of Man.	Considerable fire-ball; lighted up the scene in a very remarkable manner.	?	Several secs. remained stationary.	Horizontally from S.W. towards N.E.

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Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
First a bright light of large size, then faded with a few sparks as if going out, immediately enlarged, elongated, brilliant blue, leaving red sparks behind shading into the blue.	?	?	Moon bright in a cloudless sky.	Baker Edwards, Ph.D.
Glowing red envelope; tail ending in green; very even and somewhat permanent.	....	....	Cast shadows in the moonlight; moon six days old.	....
Parted into 7 or 8 fragments, like red-hot cinders.	?	Motion westerly	Hissing noise like quenching iron accompanied the appearance. Two minutes later, a sound was heard like the discharge of a heavy gun.	L., Correspondent to 'Manchester Guardian.'
Oval shape followed by long broad train; the flame repeated itself three or four times. It gave three distinct flashes of light upon the ground and sky.	....	?	....	J. T. Slugg.
Long tail showing all the prismatic colours.	....	Ran rather low and horizontally.	....	....
....	....	Moved N.E. to S.W. ...	....	Correspondent to 'Liverpool Mercury.'
Glare visible through closed shutters as if it lightened.	?	?	....	R. P. Greg.
A spearhead-like crescent moon five days old, with a short shaft; was followed by red star-like balls clustered behind.	10°	Sailed slowly from E. to W., with a little dip towards the horizon.	....	'Scotus,' Correspondent to 'Manchester Guardian.'
A reddish bolt issued from behind filmy clouds like a flash. The bolt or meteor afterwards separated into a number of small and brilliant particles.	?	Downwards at 45° to the horizon.	No sound could be heard.	John Jenkins.
The fireball was suddenly arrested in its progress, remained stationary for several seconds, and burst without noise.	?	Moved horizontally till it stopped and burst.	Moon clouded at the moment.	Correspondent to 'Mona Herald.'

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861.	h m					
Dec. 8	8 20 p.m.	Liverpool	....	Bluish - green light.	....	The spark spran from a littl below Capella proceeded wit scintillations t the Pole, the inflamed, crosse the head o Draco and be came suddenl extinguished.
8	8 23 p.m.	Birkenhead (Seacombe).	....	....	Darted downwards; not 4 seconds.	Appeared 8° or 9 E. of Cassiopeia burst 35° to 40 above the horizon, somewhere about N.N.W. by W.
8	8 25 p.m.	Stone, near Aylesbury.	Double of Venus; ¾ of a minute of arc.	Red flush, then a purple flush, and then a blue flush of light.	5 seconds......	From β Cephei t α Cygni (th stars doubtful).
8	8 25 p.m.	Silloth, Cumberland.	Nearly size of full moon.	Palish blue ...	5 or 6 seconds, rapid.	From altitude 50 in the S.; disappeared a littl to the N. by W.
8	8 30 p.m.	Dungannon, Ireland.	Strong glare in moonlight.	?	Lasted a few seconds.	From altitude 30 due E.
8	8 30 p.m.	Ulverston.........	?	?	?	? ....
8	About 8 30 p.m.	Liverpool.........	....	....	....	....
8	8 30 p.m.	Wakefield.........	As large as a man's head.	....	....	Quite overhead, down the western sky. Seeme to burst 50 yard off, 10 feet fro the ground.
8	8 30 p.m.	Coatbridge, Lanarkshire.	Brilliant	?	Several secs. ..	In the S.W. sky ..
8	8 40 p.m.	Lancaster.........	Large as the moon	Red	....	....
8	8 45 p.m.	Wakefield.........	Light great enough to render distant objects visible.	Purplish	?	Descended fro altitude 50° N.W to altitude 10 N.W. by W.
8	?	Manchester	Large as ¼ of the moon.	?	?	On turning, sa the meteor falling perpendicularly N.N.W.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
First a reddish spark; in combustion at the meridian; increased in intensity to apparently a large sheet of flame; extinguished suddenly.	....	....	Several shooting-stars and meteors this night.	J. Baker Edwards, Ph.D.
Light slackened at bursting, but explosion the most briiliant; fragments violet.	?	Inclined 22° towards the horizon.	Sky hazy; small halo about the moon.	D. Walker, M.D.
Star-like, and very brilliant for two seconds, then burst, and continued like a rocket, followed by coloured fragments.	?	Inclined at a great angle to the horizon.	Cloudy night, moon concealed; attention caught by crimson flush like lurid lightning.	W. Penn.
A blazing track followed it, and immediately following were many smaller globes or bulbs of fire; several bright red.	....	Descended slightly	Seen in clear sky.........	Rev. F. Redford.
Large ball of fire with coloured sparks and long train.	....	Fell down towards the earth.	....	....
Brilliant	?	E. to W.	....	....
Gave out like a stream of crimson fire, expanding like a trumpet, and then bursting without noise.	....	Fell from near the zenith straight down in the northern sky.	Light clouds; moon and stars more or less visible.	....
A tail 18 inches long issued above, then ceased, and issued at the side, till bursting with sparks.	....	....	....	....
Small red balls left behind	?	?	....	?
A tail followed, and stars about the latter portions fell from it.	....	S.E. to N.W.	After walking 200 yards a loud noise was heard like a gun.	Communicated by Albert Greg.
The light seemed uniform and ceased suddenly.	?	Appeared to move in a straight line, but the movement was irregular.	No noise or explosion...	W. R. Milner.
....	?	Fell vertical............	....	Arthur Neild.

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Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861.	h m					
Dec. 8	?	Bowdon, Manchester.	Nearly as large as the moon; brighter than the sun.	Light blue	3 seconds	From a little N.W of the zenith described an ar towards the W.
8	?	Liverpool	Very brilliant, giving out considerable glare.			At the altitude of rocket.
8	?	Llandudno	Light exceeded that of the moon, more like that of the sun.	Many coloured	2 or 3 seconds	
8	?	Settle, Yorkshire	At the flash, observer turned to examine the moon.	?	?	It appeared to com out of the moon
8	?	Newcastle-on-Tyne.	Very brilliant meteor.	?	5 or 6 seconds	?
8	In the evening.	Cartmel, Lancaster.	?	?	?	?
8	?	Douglas, Isle of Man.	Like full moon let loose in the sky.	Startlingly pale colour.	Visible 10 seconds before it burst.	
8	?	Langdale	?	?	?	Disappeared behin woods N.W.
8	?	Holcombe Hill, Bury.	?	?	?	Disappeared behin a cloud near th horizon.
8	?	Islington, London.	Larger and brighter than the largest star.			From altitude 50 or 45° W.
8		Twickenham	Most brilliant meteor; eclipsed the light of the moon.	?	?	From the Pole-sta
8	10 24 p.m.	Greenwich	=3rd mag.*	Blue	Half a second.	Across γ Aurigæ i the direction o the Pleiades.
8	10 45 p.m. to 11 5 p.m.	Birkenhead (Seacombe).	Meteors and shooting-stars.			Between Ursa Majo and Orion, S.E.
9	5 15 p.m.	Glasgow	Fine meteor	?	9 seconds	In the S.W. sky ...
9	5 30 p.m.	Hawkhurst, Kent	Brighter than 1st mag.*; large and bright meteor.	?	2½ or 3 secs.; slow motion.	Across β Ursæ Minoris; extinct halfway between β Ursæ Minoris and ζ Ursæ Majoris.
9	9 35 p.m.	Greenwich	Small		1 second	Appeared from behind a cloud, moving parallel to the horizon.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Left a long broad train behind.	?	?	A rushing sound heard during the passage.	?
Carried a luminous train, and burst at disappearance.		Moved S.E. to N.W.		Correspondent to 'Liverpool Mercury.'
Outline very irregular, oval shaped; tail formed of consecutive bulbs of fire.			Clear night	T. S. G., Correspondent to 'Manchester Guardian.'
A ball of fire	?	?	Sky free from clouds	W.H. Cockshott.
?	?	?	Many shooting-stars seen this evening at Newcastle.	Correspondent to 'Northern Advertiser,' R. Hawthorn.
?	?	?	Report very loud; alarmed the inhabitants.	Communicated by Albert Greg.
Burst in sparks like a rocket.			People greatly alarmed; no noise heard.	Samuel Simpson.
?	?	?		John Richardson.
Like six or seven falling stars.	?	They fell vertically		J. W. Wraith.
Changeable in colour, pursued by a vari-coloured tail several degrees in length; no explosion, no sparks.	40°		By memory, at same spot following day.	James Foote.
Illuminated the whole country.		Took a north-westerly direction.		E. G. P., Correspondent to 'Manchester Guardian.'
Train	7°			W. C. Nash.
			More fell here at this time than at the highest time of last August or November.	D. Walker, M.D.
?	?	?		Communicated by R. P. Greg.
Disappeared without explosion.		As if from Cassiopeia		J.F.W. Herschel.
	10°	Parallel to the horizon	Rather cloudy	J. MacDonald.

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Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861. Dec. 9	h m s 9 40 p.m.	Greenwich	=2nd mag.*	Blue	2 seconds	Fell from the neighbourhood of Orion towards the W., moving over 20° of space.
9	10 50 p.m.	Ibid.	=2nd mag.*	Blue	1 second	Across α Ursæ Majoris.
10	9 45 p.m.	Weston-super-Mare.	=2nd mag.*, α Ursæ Majoris.	Dull or smoky blue.	Less than 1 second.	Appeared near β Ursæ Minoris; disappeared near η Draconis.
10	10 30 p.m.?	Ibid.	=Capella	Bright blue	Nearly 2 secs.	Appeared azimuth 40°, altitude 20° N. of W.
11	9 12 p.m.	Royal Observatory, Greenwich.	=1st mag.*	Blue	1 to 2 seconds	From ι Aurigæ to a point a few degrees below the moon.
11	11 11 p.m.	Ibid.	=2nd mag.*	Blue	1 second	From a point a few degrees above α Orionis to γ Orionis.
11	11 23 p.m.	Ibid.	=2nd mag.*	Bluish white	1 second	Fell perpendicularly from β Geminorum towards horizon.
11	11 28 p.m.	Ibid.	=3rd mag.*	White	1 second	From ζ Tauri towards α Tauri.
13	10 0 p.m.	Weston-super-Mare.	=β Aurigæ	Smoky blue	Less than 1 second.	Appeared by Capella.
18	11 37 p.m.	Birkenhead (Seacombe).	=1st mag.*	Bluish	3½ seconds	Centre immediately below β Persei.
23	7 0 p.m.	Royal Observatory, Greenwich.	=2nd mag.*	White	1 second	From the direction of Cassiopeia to α Ursæ Majoris.
24	7 0 p.m. to 4 a.m.	London	Mostly 2nd and 3rd mag. None so large as Venus.	White and yellow; steady lights.	More swift after midnight than before; moderate.	Chiefly near the radiant before midnight, afterwards in all quarters.
24	9 0 p.m.	Woodford	Shooting-stars	?	?	In the S.
24	10 to 11 p.m.	Hitchen	Small stars	?	?	In Orion
24	11 38 34 p.m.	Deal	=α Andromedæ	White	2 seconds	From near ο to below α Andromedæ.
25	9 0 p.m.	Royal Observatory, Greenwich.	=2nd mag.*		1 to 2 seconds	Shot in a northerly direction between α and β Geminorum.
25	11 45 46 p.m.	Deal	Between α and δ Cygni.	Blue	1 second	Between α Cygni and γ Draconis, below κ Cygni.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
None	20°	Inclined		J. MacDonald.
Train	5°	N. to S., inclined		W. C. Nash.
Tailless; light alternated ten times a second.			As if a rapidly revolving light.	W. H. Wood.
Tailless	8°	Slightly inclined N. of W.	The only two meteors seen; night fair.	Id.
Train	40°	E. to W.	A fine meteor	W. C. Nash.
Train	8°	E. to W., inclined	Generally cloudy	Id.
	5°	Perpendicular	Very cloudy	Id.
		E. to W., horizontally	Very cloudy	Id.
Tailless; decreased rapidly until lost to sight.	8°	W. to E., due	Night unfavourable	W. H. Wood.
Very small train	16° to 18°	Horizontal from E. to W.	No other visible for 30 minutes.	D. Walker, M.D.
	20°			W. C. Nash.
Some left trains; courses straight.	3° to 40°, very various.		25 to 30 per hour at 10 p.m.; fewer afterwards.	A. S. Herschel.
?	?	?	Several shooting-stars within a short period.	John Hill.
Several small shooting-stars without tails.		General direction from Bellatrix to κ Orionis.		W. Penn.
Left a track lasting about 1 second.				Herbert McLeod.
Train		Almost horizontally, S. to N.		W. C. Nash.
	About 2°	Straight down		Herbert McLeod.

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Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861. Dec. 26	h m s 11 27 23 p.m.	Deal	= γ Draconis	White	1 second	Appeared betwe ξ and ζ Draconi disappeared b tween γ and Draconis.
27	7 55 p.m.	Belfast Lough	= 1st mag. *	Yellow	2 seconds	18° above the h rizon, near Aurigæ.
27	8 57 p.m.	Ibid.	Twice size of Venus	Yellow	6½ seconds	Centre at β Dr conis.
27	10 34 p.m.	Weston-super-Mare.	= Rigel	Bright blue	Near 2 seconds	At appearance b tween β and Draconis.
27	10 34 p.m.	Ibid.	= Sirius	Bright blue	2 seconds	Near λ Leonis
27	11 8 p.m.	Ibid.	ξ Ursæ Majoris (foot).	Very dark	Less than 1 second.	Between β and Draconis.
31	7 37 p.m.	Ibid.	Larger than Sirius and less than Venus.	Very bright blue.	Nearly 3 secs.	Near ζ Cygni
1862. Jan. 2	12 43 a.m.	Birkenhead (Seacombe).	= Venus	Yellow	3½ seconds	Centre 2° bel Aldebaran.
3	11 48 p.m.	Ibid.	= Procyon	Bluish	1¾ second	Centre at halfw (γ Orionis a Aldebaran).
3	11 49 p.m.	Ibid.	= 1st mag. *	Bluish	½ second	Centre almost hal way (α Orion and γ Geminorum
11	7 5 p.m.	Euston Square, London.	Brighter than Venus	More yellow than Venus, in strong contrast.	Slow movement.	Appeared below t moon; disa peared 3° abo Procyon.
11	About 7 p.m.	Edgware Road, Kilburn.	Considerably larger than Venus.	Similar to Venus.	Slow	......

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Very slight train, scarcely visible.	......	......	......	Herbert McLeod.
Tailless	12°	Almost horizontal	......	D. Walker, M.D.
Track ending the whole time of flight; somewhat radiated in appearance.	15°	To left; 52° from horizontal; down.	......	Id.
Tailless	......	A little inclined west of perpendicular to horizon.	Position at disappearance near the two stars 80 Herculis.	W. H. Wood.
Tailless	......	Inclined north side of perpendicular.	Near γ Leonis	Id.
Tailless	......	Inclined (most) west side of perpendicular, let fall from its appearance.	Near 61 Cygni	Id.
White tail 16° long; disappeared nearly simultaneously with meteor.	......	Path parallel to δ and γ Cygni, from the former towards the latter.	Over ζ Cygni. There was an interval of three seconds of time between this and another meteor. They merged from the head of Draco. This meteor in its transit passed exactly midway between α and γ Cygni; decreased before disappearance; the sky became overcast for the night; such was the case on the 28th, 29th, and 30th.	Id.
Small train	13°	To right; 45° from horizontal; down.	......	D. Walker, M.D.
Small train	10°	To right; 30° from vertical; down.	......	Id.
Small train	18°	Vertical; down	......	Id.
Head globular, surrounded by sparks; short evanescent tail of flame-like character or appearance.	?	The latter half of the path appeared curved.	Observing Venus and the moon; clear evening.	W. R. Birt.
Sparks of a golden hue emanated laterally from the head of the meteor, also leaving a considerable train of similar sparks behind it in its descent, which was particularly slow.	......	An inclined direction from beneath the moon.	......	C. Herb. Bright.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862.	h m					
Jan. 11	9 43 p.m.	Weston-super-Mare.	= Sirius	Vivid blue	?	Appeared near Bootis; disappeared 4° abov α Pegasi.
11	11 48 p.m.	Ibid.	= Jupiter	Bright yellow	3 seconds, slow motion.	Appeared near Bootis; disappeared near γ Bootis.
12	0 1 a.m.	Ibid.	= ξ (foot) of Ursa Major.	A very dark colour.	Less than 1 second.	Appeared at ι Dr conis; disappeared at γ Dra conis.
23	9 0 p.m.	Ibid.	= Capella	Rigel	2 seconds	Appeared very nea Rigel; disappeare near γ Eridani.
23	9 0 p.m.	Ibid.	= Capella	Reddishyellow	1½ second	Appeared very nea Rigel.
23	9 14 p.m.	Ibid.	= 3rd mag.*	Smoky blue	Rapid; ½ sec.	Appeared near Pro cyon.
23	9 21 p.m.	Ibid.	= 3rd mag.*	Smoky blue	Slow; 1 sec.	Appeared near Cassiopeia.
23	11 14 p.m.	Islington, London.	= 3rd mag.*	Yellow	⅔ second	From a star 4 following ω Dra conis to ι Dra conis.
23	11 29 p.m.	Ibid.	= 1st mag.*	White	½ second	From ½ (β, γ) Tri anguli toward τ Piscium.
24	8 20 p.m.	Weston-super-Mare.	= 3rd mag.*	Smoky blue	Fast; ½ sec.	Appeared midwa κ and α Dra conis; disappeared near Draconis.
24	9 28 p.m.	Ibid.	= 3rd mag.*	Smoky blue	Fast; ½ sec.	Same track a last.
24	9 28 p.m.	Ibid.	= 3rd mag.*	Smoky blue	Fast; ½ sec.	
25	12 15 a.m.	Ibid.	= 2nd mag.*	Bright blue	Moderate; ½ second.	Appeared near Draconis; passe over β Ursæ Mi noris as far a the feet.
25	11 22 p.m.	Birkenhead (Seacombe).	= Regulus	Bluish	½ second	Centre 10° belov Regulus.
25	11 22½ p.m.	Islington, London.	= 3·5 mag.*	Yellow	½ second	From ½ (τ, υ) Andromedæ toward μ Andromedæ.
25	11 25 p.m.	Ibid.	= 1st mag.*	White	0·6 second	From β Andromedæ toward ν Andromedæ.
25	11 47 p.m.	Weston-super-Mare.	= 3rd mag.*	Dull blue	½ second	Appeared near Bootis; disappeared near β Bootis.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
?	?	Path nearly perpendicular to the horizon.		W. H. Wood.
?	?	Serpentine path; very surprising.		Id.
Tailless				Id.
No track left			Auroral glare; N.W. by N.	Id.
Faint tail 3° long followed the meteor.			Rapid lightning from N.W. by N.	Id.
No tail; intermittent light; two alternations; almost disappearing.	10°	Inclined 50° southward		Id.
	8°	Along the Via lactea, northwards.	Thunder and lightning at 3 a.m., Jan. 24th.	Id.
No track left; no sparks	11°			A. S. Herschel.
No track left; no sparks	7°			Id.
No track left; no sparks	?		Radiant between κ and α Draconis.	W. H. Wood.
No track left; no sparks				Id.
No track; no sparks	12°	Parallel to horizon, E. to W.		Id.
No track left; sparks or nebulous radiations from posterior hemisphere, like a semi-corona.				Id.
No track left	7°	To right; 35° from vertical; down.		D. Walker, M.D.
No track left; some sparks	5°			A. S. Herschel.
No track left; no sparks	6°			A. S. Herschel.
No track left				W. H. Wood.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862.	h m					
Jan. 25	11 49 p.m.	Islington, London.	=2·5 mag.*.........	Faint yellow...	0·9 second ...	From 1° N. o δ to λ Cassio peiæ.
25	11 55 p.m.	Weston - super - Mare.	=3rd mag.*	Dull blue......	⅓ second	Disappeared near Bootis.
25	11 56½ p.m.	Islington, London.	=0·4 mag.*	White, brilliant, then red.	1·7 second ...	From a star 2½° N of ω Draconis 2° beyond ο Dra conis.
25	11 57½ p.m.	Ibid.	=3rd mag.*	Colourless ...	0·7 second ...	From γ to ζ Cas siopeiæ.
25	12 0 p.m.	Birkenhead (Seacombe).	=β Leonis	Bluish	½ second	Disappeared 2° below a lin joining π and Virginis.
26	0 24 a.m.	Weston - super - Mare.	=2nd mag.*	Blue	Slow; ¾ second	....
26	0 30 a.m.	Ibid.	=4th mag.*	Very dark blue.	¼ second	Appeared at we foot of Ur Major.
26	0 35 a.m.	Ibid.	=2nd mag.*	Blue	¾ second	From ξ Ursæ Ma joris to α Draconi
26	6 10 p.m.	Birkenhead (Seacombe).	=Capella............	Bluish	¼ second	Centre 2° belo and 8° E. of Persei.
26	11 44½ p.m.	Islington, London.	=0·8 mag.*.........	Yellowish......	0·8 second ...	1° S. of ι Dra conis to 1° S. o θ Draconis, an two-thirds as fa again.
27	11 24 p.m.	Ibid.	=4th mag.*	Orange colour	0·5 second ...	From ½ (κ, γ) Ca siopeiæ.
27	11 25½ p.m.	Ibid.	=1st mag.*.........	Yellow	0·5 second ...	Centre 1° preced ing σ Persei.
28	11 3 p.m.	Stone, near Aylesbury.	Tolerably large; =3rd mag.*	White light ...	2½ seconds ...	From 2° preced ing ω Cephei t ⅓ (ε, κ) Cassio peiæ; 1° neare to the latter.
28	11 4½ p.m.	Islington, London.	=0·8 mag.*.........	Yellowish......	1·3 second ...	From 1° behin ⅓ (β, π) Cassio peiæ to 1° pre ceding π Cassio peiæ.
29	7 22 p.m.	Birkenhead (Seacombe).	=1st mag.*.........	Whitish	¾ second	From ½ (ι and Ursæ Majoris.
?	7 0 p.m.	Kilburn, London.	=Venus at maximum.	White	Very slow motion.	From beneath th moon.
Feb. 2	8 15 p.m.	Burslem	Large blue light ...	Blue	Travelling slowly; ¼ minute.	....
2	8 20 p.m.	Birkenhead (Seacombe).	=Rigel	Blue	2½ seconds ...	From 2° above th belt of Orion t about 15° abov Sirius.

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Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
No track left; appeared to give out sparks.	10°			A. S. Herschel.
No track left				W. H. Wood.
α Lyræ in motion 10°; faded to dull red in 2°, and disappeared gradually. No track left; no sparks.	15°			A. S. Herschel.
No track left; sparkled	8°			Id.
No track left	18° or 20°	To left; 7° or 8° from vertical; down.		D. Walker, M.D.
Right or "off" side of circumference; hazy.				W. H. Wood.
No track left; no sparks	3°	W. to E., horizontal		Id.
No track left; no sparks	?			Id.
No track left	12°	To left; horizontal		D. Walker, M.D.
No track left; sparkled	9°			A. S. Herschel.
No track left; no sparks	8°	Parallel to γ, α Cassiopeiæ.	Clear night	Id.
Sparkled; no track left	7°	Directed from ι Persei	Only two shooting-stars from 10 to 11 p.m.	Id.
?	20°			W. Penn.
No track left; sparkled; bent downwards, and slower at last.	11°	To left; 20° from horizontal; down.	Fine passing clouds	A. S. Herschel.
No track left	6°	To left; horizontal		D. Walker, M.D.
A train of golden sparks pursued the nucleus.		Inclined downwards to left.		C. H. Bright.
Small balls like stars kept falling from it in a track like fire.		S. to N.		Correspondent to 'Manchester Guardian.'
Small train and sparks accompanied the head.		To left; 30° from horizontal; down.		D. Walker, M.D.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862. Feb. 2	h m 8 20 p.m.	Tarporley, Cheshire.	Lighted sky and landscape like a flash of lightning.	White; after bursting purple wrapped in white, then red.	6 seconds......	From nearly S. a little E. o Pleiades to nea Gemini.
2	8 20 p.m.	Liverpool	= 1st mag.*, then a large globe.	The globe was of a bluish colour.	....	First appeared a first magnitud star in the regio of Orion.
2	8 21 p.m.	Observatory, Beeston.	Not as large as the moon, but approaching to it; much brighter.	Changed to blue and pink and green.	Visible 3 secs.; slow motion.	From W.S.W., ju above Venus; then burst be hind a cloud an quickly disap peared.
2	8 30 p.m.	Manchester	In size it looked to a star as a billiard ball does to a pea.	?	6 seconds; moderate speed.	From altitude 30 E.S.E.; disap peared 20° abov horizon.
2	....	Newark	About as big as the moon, light as brilliant lightning.	Whitish colour	2 seconds ...	Directly toward the moon; burs in a cloud ten t twelve diameter off the moon.
2	....	Sheffield	....	....	....	Exploded S.W. altitude 32°; altitude 30°.
2	....	Ibid.	10 or 11 inches diameter.	Bright amber..	6 seconds......	....
2	....	Mold, Flintshire	It looked to a star as a football to a marble.	....	Moving slowly	E.S.E.; altitude 50°.
2	....	Newtown	= one-fourth of the moon.	?	Not *more* than 2 or 3 secs.	Probably kindle due E.; first seen N.E.; alti tude 45°; be came extinct N.E. by N.
2	....	Worlow	?	?	?	"Probably S.S.E to N.N.W." (H. C. S.)
2	....	Eastbourne	= half size of full moon.	Colour of moon, pale yellow.	....	Halfway betwee the Pole-star an the horizon.
2	9 15½ p.m.	Birkenhead (Seacombe).	Twice as bright as Venus.	White	2 seconds......	From α to η Dra conis.
2	10 23 p.m.	Ibid.	Jupiter..............	Blue	1¼ second ...	From 3° N. of Virginis.
2	10 25 p.m.	Ibid.	Capella..............	Pale blue	¾ second	Centre ½ (Cor Ca roli and η Urs Majoris).

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
First white, then bursting like a rocket; it took a purple hue with white light; then red; in which state it disappeared. No luminous track seen.	....	Nearly horizontal	An uninterrupted view..	W. Vicars.
Left many stars and sparks in its track of various colours.	30°	S.W. to N.E., obliquely towards the earth.	....	....
Head with a tolerably defined edge; circular; long white track; visible 20 to 25 seconds.	....	Downward, at 45° to the horizon.	Illuminated the ground so as to see quite small objects.	W. Brown; P. Parr.
Perfectly round; very little train; vanished quietly.	?	Fell almost vertically ...	Thin strata of fleecy clouds.	
Circular; luminous track; lasted half a minute.	....	At 45° downward	Moved along among belts of clouds.	A. H. Allcock.
Appeared to explode twice	....	S.E. to N.W.; E. to W.	....	Communicated by H. C. Sorby, Messrs. Roberts, Mappin, and Watson.
Perfectly round; burst suddenly.	....	From altitude 40° E.; moved 40° N.W.	....	W. P. W. Buxton; Mr. Furniss.
Emitted stars, and left a large track of sparks.	....	Horizontal	....	Correspondent to Carnarvon Paper.
Head pear-shaped, encircled by red fiery glare. Comet-like tail one yard in length, fringed with blue; no track left.	....	In an oblique direction towards the north horizon.	....	R. Owen.
?	?	From S. to N., or a little W. of N.	....	C. H. B. Hambly.
After shooting across the sky and disappearing, burst forth again and exploded like a rocket.	....	N. to N.W., downwards	....	John Hall, jun.
Orange-red train with sparks; one second.	....	To left; 45° from horizontal; down.	Slight curve in the direction.	D. Walker, M.D.
No track left	6°..........	Vertical; down	....	Id.
No track left	12°	To left; 45° from horizontal; down.	....	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862.	h m					
Feb. 2	10 54 p.m.	Birkenhead (Seacombe).	=Castor …………	White ………	½ second ……	From χ to ι Urs Majoris.
2	11 11 p.m.	Ibid. …………	=Cor Caroli ……	White ………	3 seconds……	Centre ⅓ (Cor Caroli and Arcturus), 2° highe
2	11 30 p.m.	Ibid. …………	=Cor Caroli ……	White ………	½ second ……	Centre ½ (β Leoni and α Com Berenicis).
3	9 0 p.m.	Kilmarnock, Glasgow.	Quarter diameter of moon, or 3 times Venus at maximum.	White ………	More than half a minute.	Appeared close t Pollux; disappeared close t Aldebaran.
4	11 46 p.m.	Weston-super-Mare.	=Capella…………	Bright blue …	1½ second …	Appeared near Cassiopeiæ.
9	11 41 p.m.	Birkenhead (Seacombe).	=Jupiter…………	Blue ………	½ second ……	Centre 2° below Ursæ Majoris.
10	11 32 p.m.	Ibid. …………	=Arcturus ………	White ………	½ second ……	Centre between Arcturus and Miræ.
18	8 37 p.m.	Greenwich ……	=3rd mag.* ……	Blue ………	1 second ……	From direction o Capella; disappeared near Arietis.
18	9 12 p.m.	Ibid. …………	=3rd mag.* ……	Blue ………	Nearly 1 sec.	From ζ Tauri acros α Orionis.
18	11 12 p.m.	Islington, London.	=γ Cassiopeiæ …	White ………	0·6 second …	½ ι Cassiopeiæ, A Camelopardal to ⅔ (χ, η) Persei.
19	0 23 a.m.	Birkenhead (Seacombe).	Twice diameter of Jupiter.	Yellow ……	¾ second ……	From 1½° to righ of η Draconis.
19	11 32 p.m.	Islington, London.	=4th mag.* ……	Yellow ……	0·2 second …	Centre ⅓ (γ Cephe and β Cassiopeiæ).
19	11 50 p.m.	Ibid. …………	=Sirius …………	White ………	1·3 second …	From ⅓ (Polaris, β Aurigæ) to ⅔ (θ to η) Aurigæ.
19	12 10 p.m.	Ibid. …………	=α Aquilæ ………	White ………	½ second ……	Appeared near Draconis.
20	8 45 p.m. to 9 30 p.m.	Weston-super-Mare.	=2nd and 3rd mag. shooting-stars.	? ……………	? ……………	……………………
20	11 p.m. to 12 p.m.	Ibid. …………	=3rd mag. shooting-stars.	? ……………	? ……………	Centre ½ (γ Cephei, β Cassiopeiæ).
20	11 32½ p.m.	Islington, London.	=ι Cassiopeiæ …	Yellow ……	0·25 second…	……………………
21	10 57 p.m.	Greenwich ……	=2nd mag.* ……	White ………	About 2 secs…	……………………
21	11 5 p.m.	Islington, London.	=α Persei ………	Yellow ……	0·6 second …	1½° following Aurigæ to 1½ following β Aurigæ.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
No track left		To left; 30° from horizontal; down.		D. Walker, M.D.
A small track left	10°	To right; 30° from horizontal; down.		Id.
No track remained	5°	To left; 30° from vertical; down.		Id.
Steadylight, very brilliant, like the electric light, or a fine ball; no train.	?	Parallel to γ Orionis and α Orionis.		Robert Craig, jun.
Smoky appearance; semi-corona.	15°	E. to W., inclined 10° W.		W. H. Wood.
No track remained	6°	To left; 30° from horizontal; down.		D. Walker, M.D.
No track left	5°	Vertical; down		Id.
None				W. C. Nash.
				Id.
No track left; no sparks; brightest at middle.	10°	Almost N. to S.		A. S. Herschel.
Fullest and brightest at centre of its flight.	11° or 12°	Vertical; down	One meteor in an hour.	D. Walker, M.D.
Serpentine flight; three undulations ½° wide.	3°	Direct from Polaris		A. S. Herschel.
No track; no sparks		Nearly from Polaris		Id.
No track left	10°	From Polaris	Radiant Polaris	Id.
A considerable display	?	Radiant in Perseus; N. P. D. 33°; A. R. 29°.		W. H. Wood.
A considerable display; all tailless save one.	?	Radiant Polaris	Tailed star; 1st magnitude; blue; 10° in 3 seconds; tail ascended and dissipated like steam.	Id.
No track left; no sparks	3°	From Polaris		
None	20°	Fell from zenith towards the western horizon.		J. MacDonald.
No track left; no sparks	8°	From Polaris		A. S. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862.	h m					
Feb. 21	11 15 p.m.	Islington, London.	= γ Cassiopeiæ ...	Yellow	1 second	γ Cephei to Cephei; ½° following.
21	11 15 p.m.	Greenwich	As bright as Jupiter.	Blue	About 2 secs...	....
23	9 25 p.m.	Liverpool	Magnificent meteor	....	....	....
23	9 25 p.m.	Weston-super-Mare.	= half diameter of moon.	Vivid red light	1½ second ...	From N.N.E. half E. altitude 20°; to N. altitude 18½°.
23	....	Liverpool, Wallisby, Cheshire.	Bright light filled the streets.	A cold light, not flame-coloured.	Leisurely	Moved as if from over Manchester into Wales. Great Bear to Orion, horizontally.
23	....	Bramboro, Chester.	A bright light thrown from the sky.	....	....	Origin near Jupiter
23	....	Cross Houses, Salop.	Exceedingly brilliant.	?	Flashes 2 secs., then ran across the sky.	From S.W. by S., along the horizon at a great altitude; probably 40° or 50° between Jupiter and Ursa Major.
23	....	Salop	....	....	....	From a great height, nearly to the ground.
23	9 30 p.m.	Weston-super-Mare.	= 2nd mag.*	Blue	?	From Cassiopeia ...
Mar. 3	9 8 p.m.	Ibid.	= 2nd mag.*	Blue	1½ second......	Appeared close to Sirius.
3	9 29 p.m.	Ibid.	= one-eighth of moon.	Pale red	2½ secs., slow..	....
Apr. 3	11 25 p.m.	Islington, London.	= 4th mag.*	White	0·7 second ...	Centre 1° S. of *p q* Camelopardali.
4	8 10 p.m.	Weston-super-Mare.	= 1st mag.*	Blue	½ second	From Sirius .....
4	9 5 p.m.	Ibid.	= 1st mag.*	Blue	½ second	From Jupiter ......

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
No track left; no sparks...	15°	From Polaris		A. S. Herschel.
Slight train		In the N., fell from the zenith, disappearing behind the houses.		J. MacDonald.
A bar of light remained about 20 seconds after the first appearance of the meteor.		E. to W., at an angle of about 80° with the horizon.	The tail faded gradually, no change.	Correspondent to 'Liverpool Mercury.'
Starlike meteor; became suddenly extinct, leaving a bar of red light 25° in length, fluctuating between red and orange, and lasting 8 seconds until disappearance.	25°	E. to W., nearly horizontal; west end depressed 2° or 3°.		W. H. Wood.
No explosion; long distinct train of light, disappearing slowly like smouldering twine.		From E. to W. by S.		Studley Martin.
On turning round, two bars of white light were seen, which endured fifteen seconds. Their length together was 26°; the south bar faded sooner than the north.		Slightly inclined to the horizon.	Jupiter appeared to shine brighter when the bars disappeared than he did before.	T. Juman.
Two flashes like lightning, then ran along the horizon in one long broad line, which endured five minutes, not changing.		Parallel to the horizon, yet in a descending position, inclining especially to the S.	The stars seemed to go out on that side of the hemisphere, and did not recover their brightness for half an hour.	James Caswell and Son.
		Vertical; down		
?	?	A little inclined	Sky obscured at 10 p.m.	W. H. Wood.
No track left	8°	To left; 30° from vertical; down.		Id.
Planetary, or better, a globe.		Perpendicular to the horizon.		Id.
Momentary train	8°	Directed from o Ursæ Majoris.	One star in an hour; N.W.; cloudless.	A. S. Herschel.
Sky overcast with haze		Perpendicular to horizon.	Fell one per hour	W. H. Wood.
Sky covered with thick haze.	10°	Perpendicular to horizon.		Id.

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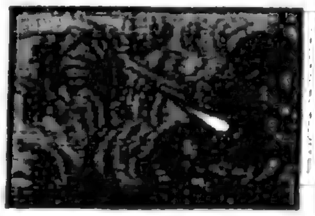
Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862.	h m					
Apr. 14	7 42 p.m.	Clerkenwell, London.	8 to 10 times as bright as Jupiter.	White	3 seconds......	From 10° or 12 over Jupiter t altitude 32°, S by W.
17	10 10 p.m.	Hitchen	Fine meteor.........	....	3 seconds......	From ½ (α Ursæ Ma joris and Polaris to centre of Co rona Borealis.
20	8 30 p.m.	Greenwich Hill..	Larger than Jupiter	?	2 seconds ...	Between *p* and Camelopardali.
23	8 56 p.m.	Weston-super-Mare.	Larger than 1st mag.*	White	Slow; 1½ sec.	16 Draconis to γ Draconis, close and paralle to α and γ Dra conis.
23	9 50 p.m.	Ibid.	Nearly as large as Jupiter.	Deep yellow...	Slow; 2 secs...	From Arcturus t 18*h* Bootis.
23	10 35 p.m.	St. John's Wood, London.	Brilliant body of light.	Bluish coloured.	7 seconds......	Between N. and E. altitude 45°.
24	10 26 p.m.	Weston-super-Mare.	=1st mag.*.........	Brilliant blue..	½ second	At appearance nea 41 and 42 Ca melopardali.
24	11 33½ p.m.	Islington, London.	=Pollux	Pollux	0·4 second ...	From 1° S. o Camelopardus.
25	10 30 p.m.	Weston-super-Mare.	=Spica Virginis ...	Spica Virginis	¾ second	At appearance nea 66 Virginis.
25	10 30¼ p.m.	Ibid.	=Spica Virginis ...	Spica Virginis	¾ second	66 Virginis ....
26	10 52 p.m.	Ibid.	=Venus	Venus	1 second	From π 1 Cygni passing betwee the head stars o Lacerta.
26	10 52½ p.m.	Birkenhead (Seacombe).	=Jupiter	Blue	2¼ seconds ...	Close to μ Her culis.
27	8 42 p.m.	Greenwich	=2nd mag.*	Reddish	1 to 2 seconds	From the directio of Ursæ Majori towards the horizon past Arcturus.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Pear-shaped; no track visible through clouds; faded gradually, and disappeared quietly; very slight train.	40°	To right; 20° from horizontal; down.	 Strong twilight; quite overcast; rain falling.	T. Crumplen; A. S. Herschel.
Left a train like a sky-rocket.				Communicated by W. Penn.
Stationary; varied little in brightness.				W. Airy.
Pursued by faint phosphorescent train.				W. H. Wood.
No track; disappeared and reappeared three or four times.				Id.
Rocket-like, but kite-shaped; left a few sparks for half a second on dying out.	2° or 3°	Horizontal, W. to E., inclining downwards at last.		Id.
None	5°	Inclined west of ⊥	Increased in brilliancy	Id.
No track; no sparks; brightest in the middle.	7°	To left; 35° to 40° from vertical; down.	Only one other star in the hour; very faint; cloudless.	A. S. Herschel.
None	5°	Ditto, west side of vertical, at an angle of 75°.		W. H. Wood.
None	5°	Inclined 65° west of ⊥		Id.
None	8°	Inclined	Appeared first as a second magnitude star, and gradually increased until equal Venus, when it became suddenly extinguished.	Id.
Train visible three seconds; burst at last with strong light; pink, and bright as Venus.	15°	To left; 30° from vertical; down.		D. Walker, M.D.
	15° to 20°			W. C. Nash.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862.	h m					
Apr. 27	8 51 p.m.	Greenwich	=2nd mag.*	Yellow	1 second	Dropped from near Polaris in a N. by E. direction towards the horizon.
27	10 10 p.m.	Birkenhead (Seacombe).	=Venus	Blue	½ second	5° beneath ½ (β and γ Herculis).
27	10 50 p.m.	Ibid.	=Jupiter	Whitish	½ second	Centre ½ (γ Serpentis and γ Herculis).
27	11 25 p.m.	Ibid.	=α Lyræ	Bluish	½ second	Centre 2° below γ Serpentis.
28	10 46 p.m.	Weston-super-Mare.	=2nd mag.*	Blue	1½ second ...	From ζ (Crateris) to γ (Corvis).
29	9 53 p.m.	Ibid.	=1st mag.*	White	1 second, fast..	From Ursa Major...
29	11 6 p.m.	Islington, London.	=Capella	Capella	0·9 second ...	κ, to 1½° S. of θ Cassiopeiæ.
29	11 33 p.m.	Ibid.	=o Ursæ Majoris..	o Ursæ Majoris	0·1 second ...	From ½ (q, p) to L Camelopardali.
29	11 37½ p.m.	Ibid.	=o Ursæ Majoris..	o Ursæ Majoris	0·2 second ...	From f Lyncis ...
29	11 55 p.m.	Ibid.	Half as bright as Jupiter.	White, then red.	4·5 seconds; exceedingly slow.	From μ Cephei to within 4½° of Pegasi.
May 21	10 27 p.m.	Weston-super-Mare.	=2nd mag.*	Blue	1½ second ...	From α Cephei towards β Cassiopeiæ.
24	10 10 p.m.	Ibid.	=1st mag.*	Yellow	2 seconds	From Right Ascension 1°, Declination 51° N. to Right Ascension 13°, Declination N. 48°.
25	10 40 p.m.	Ibid.	=1st mag.*	Blue	1½ second ...	From γ Sagittæ to α Delphini.
25	10 55 p.m. or 11 p.m.	Ibid.	=1st mag.*	Blue		S.W.; altitude 30°
	No meteors	seen throughout	the month of June			
July 12	10 41 p.m.	Weston-super-Mare.	=Sirius	White	¾ second	From γ Cassiopeiæ to λ Persei.
16	10 45 p.m.	Ibid.	=2nd mag.*	Blue	(Fast) ½ sec. ..	Head of Cepheus...
19	11 17 p.m.	Ibid.	=Venus	Yellow	4 seconds	From stars 4, 5, and 6 Camelopardali to 14 and 15 Leo Minor.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Faint train	25°			W. C. Nash.
Burst with a very bright flash; track remained half a second.	18°	To right; 45° from horizontal; down.		D. Walker, M.D.
Left a small track	8°	Vertical; down		Id.
Left a slight track	10°	To left; horizontal		Id.
None				W. H. Wood.
None				Id.
Left no track				A. S. Herschel.
No track; no sparks	1°	Horizontal		Id.
No track; no sparks	4°	Directed from β Ursæ Majoris.		Id.
Left no track. Brilliance vanished suddenly at β Lacertæ, remaining 12°; light red (Mars at maximum robbed of his rays); very intermittent or vacillating; 2·3 seconds; died out.	22°	Course straight, but as if wrinkled in the last half. α Cephei to η Pegasi.	Brilliance in first half of flight uniform; commencement not seen; diameter of dull disc 1′.	Id.
None	10°	Inclined		W. H. Wood.
No train	10°	Inclined	A remarkable object, resembling in shape an elongated spindle, gradually increased and decreased in size; the magnitude given refers to its centre.	Id.
Very faint tail		Inclined		Id.
None		Inclined	The data not accurate...	(Communicated to W.H.Wood.)
				W. H. Wood.
	10°	⊥		Id.
White tail 15° long		Inclined	Burst with sparks; tail not durable.	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862.	h m					
July 19	11 30 p.m.	Weston - super - Mare.	=2nd mag.*	Blue	¼ second	From β Cassiope
21	11 7 p.m.	Ibid.	=3rd mag.*	Blue	½ second	From Polaris
21	11 7 p.m.	Ibid.	=3rd mag.*	Blue	½ second	Head of Cepheus
21	11 10 p.m.	Ibid.	=Jupiter (planetary).	Ruddy	3 seconds	From α Draconis stars H 30 and Ursæ Majoris.
27	9 50 p.m.	Ibid.	=1st mag.*	Yellow	1 second	From γ Bootis
27	10 22 p.m.	Greenwich	=3rd mag.*	Yellowish white.	About 2 or 3 seconds.	From a few degre to the east Ursa Minor, passing throu that constell tion, and al through Ur Major, disa pearing abo 10° above t horizon.
28	11 1 p.m.	Weston - super - Mare.	=2nd mag.*	Blue	1 second	From H 30 and Ursæ Majori passed betwe α and β Ur Majoris.
28	11 8 p.m.	Ibid.	=3rd mag.*	Blue	½ second	From θ Draconis.
28	11 12 p.m.	Ibid.	=3rd mag.*	Blue	½ second	Head of Cepheus.
28	11 17 p.m.	Ibid.	=2nd mag.*	Blue	¼ second	γ Andromedæ
28	11 43 p.m.	Ibid.	=1st mag.*	Blue	½ second	φ Pegasi
28	11 48 p.m.	Ibid.	=2nd mag.*	Blue	½ second	5° below α Pegas
28	Midnight	Ibid.	=1st mag.*	Blue	½ second	From H 30 and Ursæ Majori passed betwe α and β Ur Majoris.
29	0 10 a.m.	Ibid.	=1st mag.*	Blue	½ second	From ρ to φ Urs Majoris.
29	0 32 a.m.	Ibid.	=2nd mag.*	Blue	½ second	From ι Cassiopeiæ.
31	10 18 p.m.	Greenwich	=2nd mag.*	Bluish white	1 to 2 seconds	Shot from α Aquarii towar the zenith a disappeared short distan from α Cygni.

ppearance ; Train, if any, and its Duration.	Length of Path.	Direction ; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Nearly stationary			Like a gas-light suddenly lit and put out.	W. H. Wood.
	15°	Inclined N.	These meteors were within one second of each other.	Id.
	10°	Inclined N.		Id.
Red tail 8° long			A beautiful meteor, like a fiery comet, slowly wending its way ; tail very thick and bright came from the nucleus in curls like steam, until the nucleus was wholly diffused into the tail, which remained one second after.	Id.
Very faint tail	12°	Towards the W.		Id.
None			Very fine; cloudless	J. MacDonald.
None	15°			W. H. Wood.
None	10°	Towards N.		Id.
None	10°	Towards N.		Id.
None	2°	Towards N.		Id.
	10°	Towards N.		Id.
	10°	Towards N.E.		Id.
	15°			Id.
	12°			Id.
	12°	Towards N.		Id.
Train throughout	50°		A very fine meteor	W. C. Nash.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862.	h m					
July 31	10 34 p.m.	Greenwich	=2nd mag*.	Bluish white...	1 second	From a point b tween α and Pegasi towar horizon across Aquarii.
31	10 53 p.m.	Ibid.	=3rd mag.*	Blue	1 second	From α Andr medæ to ξ P gasi.
Aug. 1	10 10 p.m.	Ibid.	=2nd mag.*	Blue	1 second	From the directi of α Persei t wards north h rizon, passing few degrees b low Capella.
1	10 48 p.m.	Ibid.	=2nd mag.*	Blue	1 to 2 seconds	From the directi of Cassiopei disappeared ne Delphinus.
1	10 57 p.m.	Ibid.	=2nd mag.*	Blue	1 to 2 seconds	Crossed α Dracon and disappear in the centre Ursa Major.
1	11 18 p.m.	Ibid.	=2nd mag.*	Blue	1 second	Started between and α Pegasi disappeared ne α Andromedæ.
2	10 39 p.m.	Weston - super - Mare.	=Mars	Greenish	3 seconds......	From γ Serpenti to Arcturus.
2	10 42 p.m.	Ibid.	=1st mag.*	Blue	1 second	From ζ Pegasi.....
2	11 45 p.m.	Ibid.	=1st mag.*	Yellow	1 second	From γ Serpentis..
2	11 50 p.m.	Ibid.	=1st mag.*	Blue	1 second	From θ Pegasi.....
2	11 54 p.m.	Ibid.	=2nd mag.*	Blue	½ second	Head of Capri cornus.
2	11 55 p.m.	Ibid.	=2nd mag.*	Blue	½ second	ζ Pegasi ....
2	11 58 p.m.	Ibid.	=1st mag.*	Blue	½ second	γ Serpentis ....
3	0 55 a.m.	Ibid.	=1st mag.*	Blue	½ second	γ Aquarii ....
3	0 59 a.m.	Ibid.	=2nd mag.*	Blue	½ second	19 Aquarii ....
3	1 3 a.m.	Ibid.	=Mars	Ruddy	2½ seconds ...	R. A. 20 minutes D. S. 3° to R. A 23 hours 20 minutes, D. S. 3°.
3	1 15 a.m.	Ibid.	=3rd mag.*	Blue	½ second	β Pegasi ....
3	1 19 a.m.	Ibid.	=1st mag.*	Yellow	½ second	Markab ....
3	1 22 a.m.	Ibid.	=2nd mag.*	Blue	½ second	....
3	1 24 a.m.	Ibid.	=2nd mag *	Blue	½ second	Markab ....
3	1 35 a.m.	Ibid.	=Capella...........	Blue	1 second	α Andromedæ over Scheat.
3	1 44 a.m.	Ibid.	=2nd mag.*	Blue	¾ second	(36) Ursæ Majoris to horizon.
3	10 15 p.m.	Greenwich	=3rd mag.*	Blue	1 second	From ι Pegasi to π Aquarii.
3	10 47 p.m.	Weston - super - Mare.	=2nd mag*.	Blue	½ second	α Pegasi ....

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ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Train	15° to 20°			W. C. Nash.
	27°			Id.
Small train	10°			Id.
Train	25°			Id.
Train	20°			Id.
Train	15° to 20°			Id.
Red tail			A red thick tail curled off from nucleus and disappeared within the latter.	W. H. Wood.
None	10°	Horizontal		Id.
None	10°	Towards S.	Great numbers left unrecorded between 10^h 42^m and 11^h 45^m.	Id.
White tail	15°	Horizontal, westward	Tail endured 2½ seconds	Id.
None	10°	Horizontal, S.		Id.
White tail	10°	Horizontal, S.	Tail endured 2 seconds	Id.
None	5°			Id.
None	10°	Near ⊥		Id.
		Horizontal, southwards.		Id.
Red tail		Horizontal, southwards.		Id.
None	5°	Northwards		Id.
None	8°	⊥		Id.
None	8°	S.		Id.
		N.		Id.
White tail; 2½ seconds	15°		Tail brightest in centre, fading at ends.	Id.
None		Perpendicular		Id.
Faint train	13°		Hazy	W. C. Nash.
None	10°	Inclined E.		W. H. Wood.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862.	h m					
Aug. 3	10 52 p.m.	Weston-super-Mare.	=2nd mag.*	Blue	½ second	From (12) (13) melopardali.
3	10 56 p.m.	Greenwich	=2nd mag.*	Blue	1 second	From α Peg two-thirds of distance to Pegasi.
3	10 57 p.m.	Weston-super-Mare.	=3rd mag.*	Blue	½ second	From (12) (13) melopardali.
3	11 0 p.m.	Greenwich	=1st mag.*	Blue	1 to 2 seconds	Moved from a p midway betw β and α Pe towards horiz disappearing near β Pisciu
3	11 11 p.m.	Weston-super-Mare.	=3rd mag.*	Blue	½ second	From (12) (13) melopardali.
5	9 43 p.m.	Ibid.	Nearly =Venus ...	Deep yellow...	1½ second ...	From ι Cassiop to R. A. 50 nutes, Dec. 83°.
5	9 54 p.m.	Ibid.	=Capella...........	Capella	½ second	From ζ Cassiop to γ Androme
5	10 37 p.m.	Greenwich	=1st mag.*	Blue	1 second	Shot rapidly front of clouds from rection of Cas peia, across D conis, passi above Ursa Minor.
5	11 0 p.m.	Weston-super-Mare.	=Sirius	White	¾ second	From δ Aurigæ 66 Aurigæ.
7	9 5 p.m.	Greenwich	=2nd mag.*	Bluish white...	1½ second ...	Fell from a p situated near centre of U Major to a p about 12° bel
7	9 5 p.m.	Weston-super-Mare.	=Sirius	Vivid blue ...	1½ second ...	From mouth Ursa Major t Ursæ Majoris
7	10 32 p.m.	Greenwich	=2nd mag.*	Blue	1 second	From a point n β Andromeda γ Pegasi.
9	9 55 p.m.	Weston-super-Mare.	=2nd mag.	Blue	½ second	H 24 Camelop dali to β U Majoris.
9	10 45 p.m.	Ibid.	=Sirius	White	1 second	ι Cassiopeiæ Polaris.
9	10 54 p.m.	Ibid.	A little less than Mars.	Bright yellow	¾ second	H 5 Camelopar to head of Ly
9	10 54 p.m.	Ibid.	=Capella...........	White	½ second	β Cassiopeiæ ..
9	11 8 p.m.	Ibid.	=β Ursæ Majoris..	Blue	½ second	From Polaris between β an Ursæ Minoris

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
None	5°	Nearly horizontal, eastward.		W. H. Wood.
Small train	11°			W. C. Nash.
None	20°	To N.W.		W. H. Wood.
Train	20°			W. C. Nash.
None	15°	To N.W.		W. H. Wood.
Red tail; length 12°; duration half a second.		Serpentine; made two deflections.	Increased from a yellow 2nd mag.*; tail curled off thickly till all consumed.	Id.
Short streak			A very stormy night; observations between clouds; lightning.	Id.
Train	25°	E. to W.	Clouds in all directions.	W. C. Nash.
				W. H. Wood.
None	12°	Perpendicular	Fine clear night; moon very bright.	J. MacDonald.
			Bright moonlight	W. H. Wood.
Train	25°		Moon very bright. August 8th to 13th were cloudy nights at Greenwich.	W. C. Nash.
None			August 8th overcast and wet at Weston-super-Mare.	W. H. Wood.
White tail, 15°; endured 2 seconds.			Bright moonlight night.	Id.
			Suddenly blotted out when most brilliant.	Id.
None	3° to zenith			Id.
None				Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862.	h m					
Aug. 9	11 11 p.m.	Weston - super - Mare.	=Capella...........	Bright blue ...	1 second	Star-cluster, h of Auriga to horizon.
9	11 17 p.m.	Ibid.	=δ Ursæ Majoris..	Blue	½ second	α Draconis to b of Ursa Mino
10	0 15 a.m.	Ibid.	=3rd mag.*	Blue	¼ second	Head of Lynx to horizon.
10	0 25 a.m.	Ibid.	=α Lyræ...........	α Lyræ.........	1 second	β Ursæ Majo to χ Ursæ M joris.
10	0 28 a.m.	Ibid.	=Sirius	White	¾ second	η Aurigæ to ζ A rigæ.
12	10 49 p.m.	Trafalgar Square, London.	=1st mag.*.........	White	Not more than 2 or 3 secs.	From 85 to 62 H culis.
12	10 50 p.m.	Hawkhurst, Kent	=α Ursæ Majoris..	White	1·5 second ...	From ½ (ζ U Majoris and Bootis) to Bootis.
12	11 9 p.m.	Ibid.	First α Lyræ, then Capella, then disc=Jupiter.	White, then red, then dull.	5 seconds ...	On a line fr β Bootis to Ursæ Majo Began 2° fr the first sta vanished at distance fr second star= γ Ursæ Majo short of second.
18	9 17 p.m.	Greenwich	=1st mag.*.........	Yellowish white.	1 second	From α Lyræ wards the S. horizon.
18	9 55 p.m.	Ibid.	Small	....	2 seconds......	From α Cygni wards the W. nearly a ho zontal directio
18	10 7 p.m.	Ibid.	=2nd mag.*	....	2 seconds......	From Corona realis towar the Great Bea
18	10 31 p.m.	Ibid.	=2nd mag.*	Bright blue ...	3 seconds......	From the neig bourhood of certa, disappe ing about twe degrees below.
18	10 42 p.m.	Ibid.	Very small	....	1 second	From the nei bourhood of laris towards northern horiz for about 5°.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
None			A remarkable display of Aurora Borealis; commenced at 11^h 10^m; I therefore omitted several meteors of 2nd and 3rd magnitude, from α and η Draconis and β and γ Ursæ Minoris, between 11^h 10^m and 11^h 45^m whilst taking notes.	W. H. Wood.
None				Id.
				Id.
?				Id.
?			Cloudy at 0^h 45^m a.m.	Id.
Left a slight track			Cloudy and conjectural.	T. Crumplen and J. Townsend.
Sparkled in appearance		To left; slightly downward.	Clear sky	A. S. Herschel.
Grew to = α Lyræ; then left red sparks in a ball, which moved less quickly, and expired 4° in the rear; nucleus then became dull with visible disc.		To right; slightly downward.	Began to give off sparks between Cor. Caroli and ι Ursæ Majoris; disc travelled in barren state 5° to extinction.	Id.
Slight train				J. MacDonald.
None			Fine night	Id.
Slight train				Id.
None				Id.
				Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862.	h m					
Aug. 18	11 17 p.m.	Greenwich	=1st mag.*	Bright green...	3 seconds......	Appeared at a point about 20° above the horizon due S.; passed to a point situated about 10° above the horizon nearly due E.
19	9 44 p.m.	Ibid.	=3rd mag.*	Bluish white..	1 second	Fell from the zenith towards the N for a distance o 10°.
19	10 32 p.m.	Ibid.	=2nd mag.*	Blue	1 second	From a point nea Capella to β Aurigæ.
19	10 46 p.m.	Ibid.	=1st mag.*	Blue	About 0·5 sec.	Started near α Andromedæ, an passed across Pegasi.
22	0 30 a.m.	Weston-super-Mare.	=1st mag.*	White	½ second	From β Ursæ Majoris.
22	9 15 p.m.	Greenwich	=1st mag.*	White	2½ seconds ...	From Polaris towards the N. after moving ov a space of 12° it disappeare behind a rang of houses.
22	9 47 p.m.	Ibid.	Small	White	1 second	From the zenit towards the W for 5°.
22	10 0 p.m.	Ibid.	....	....	....	From the neighbourhood of Cygni towar the W. for 17°
22	10 7 p.m.	Weston-super-Mare.	=2nd mag.*	Bright blue ...	2 seconds......	From the mouth Ursa Major the fore-foot.
22	10 22 p.m.	Greenwich	=2nd mag.*	Bright blue ...	2 seconds......	Appeared in t S. at an elev tion of 50°, di appearing in t S.W. at an el vation of abo 30°.
22	10 36 p.m.	Ibid.	=1st mag.*	White	1 second	From α Lyræ t wards the S. f a few degrees.
22	10 43 p.m.	Weston-super-Mare.	=Sirius	White	1½ second ...	From the mouth Ursa Major the fore-foot.
22	10 45 p.m.	Greenwich	Small	....	1 second	Appeared in t N. about 10° the W. of U Major, pas through that c stellation, dis pearing about to the E.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
A train of brilliant red sparks, remaining nearly one second after the meteor had disappeared.		Nearly horizontal		J. MacDonald.
None	10°			Id.
Train	8°			W. C. Nash.
Train	15° to 20°	E. to W.		Id.
	3° S.W.			W. H. Wood.
Light train of red sparks, which lingered for half a second or more after the body of the meteor had disappeared.				J. MacDonald.
None	5°			Id.
Brilliant train of red sparks	17°			Id.
Faint streak				W. H. Wood.
Slight train	20°	Inclined		J. MacDonald.
None				Id.
?				W. H. Wood.
				J. MacDonald.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862.	h m					
Aug. 22	11 30 p.m.	Weston-super-Mare.	=Jupiter...........	Very bright blue.	2½ seconds ...	(4, 2, 6) Lyncis ...
22	11 32 p.m.	Ibid.	=Sirius	White	1½ second ...	ρ to α Bootis ......
23	0 2 a.m.	Ibid.	=2nd mag.*	Blue............	½ second	ι Ursæ Majoris ...
23	10 43 p.m.	Ibid.	=1st mag.*	Bright blue ...	1 second	Halfway betwee λ Draconis and ι Ursæ Majoris.
23	11 30 p.m.	Ibid.	=2nd mag.*	Blue	1 second	α Draconis ....
23	11 35 p.m.	Ibid.	=1st mag.*	White	1½ second ...	76 Ursæ Majoris passing over Ursæ Majoris.
23	11 49 p.m.	Ibid.	=1st mag.*	White	½ second	δ to β Cephei .....
24	0 55 a.m.	Ibid.	Venus+globular...	Orange.........	2 or 3 seconds	From 35° to 40 altitude; azimut S.S.W.
24	9 17 p.m.	Greenwich	Small	Bluish white..	1 second	From the zenith towards the W for a distance o 15°.
24	9 45 p.m.	Ibid.	=2nd mag.*	....	3 seconds......	From Polaris towards Ursa Major for about hal the distance.
25	9 23 p.m.	Ibid.	=1st mag.*	Blue	1 to 2 seconds	Started near ι Andromedæ, and disappeared a little to the righ of γ Arietis.
27	9 11 p.m.	Greenwich Park	=2nd mag.*	Blue	1 second	From the directio of α Corona Borealis, passe to the left o Arcturus toward the horizon.
27	9 58 p.m.	Greenwich	=1st mag.*	....	1 second	From Polaris towards the W.
27	10 19 p.m.	Ibid.	Small	....	1 second	From the zenit towards the E.
27	11 17 p.m.	Ibid.	=Jupiter...........	....	5½ seconds ...	From the zenit towards the E for 17°.
28	9 18 p.m.	Ibid.	=2nd mag.*	....	1 second	From α Lyræ towards the S. horizon.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
An adhering short white tail.	20°+	Nearly ⊥	A beautiful meteor illuminated the elements; finished its course behind a piece of detached cumulus cloud. A detonation was heard similar to the explosion of a sky-rocket in mid-air, but strange to say, before its disappearance; a detonation was also heard by J. H. Smyth Pigott, Esq., Lord of the Manor.	W. H. Wood.
None				Id.
	3° N.			Id.
	20° N.			Id.
None	25° N.			Id.
	20°			Id.
None				Id.
Long yellowish tail, 4 secs.		Path horizontal from S.S.W. to W.	Illuminated the heavens; termination not seen; threw off red sparks in its course like a rocket.	Id.
None	15°			J. MacDonald.
Light train of blue sparks.				Id.
Train	20°		Hidden for a short period behind clouds.	W. C. Nash.
Train	About 15°			Id.
None				J. MacDonald.
Light train				Id.
	17°			Id.
None				Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862. Aug. 28	h m 10 47 p.m.	Greenwich ……	=2nd mag.* ……	Blue ………	1 second ……	From the neigh bourhood of Lyræ toward the W.
29	11 29 p.m.	Ibid. …………	Very small ………	………………	1 second ……	From the neigh bourhood of Urs Major toward the N., dis appearing be hind a row o houses.
Sept. 19	About 5 40 p.m.	Dorking ………	Saw a most brilliant light.	? ……………	For about ¼ of a minute.	The meteor appear ed to be abou 50° from the ho rizon, and nearl W. or S. of W.
19	5 45 p.m.	Delmonden, Hawkhurst.	Like a cricket-ball..	Bright white...	2½ to 3 seconds	From altitude 36° 5½° S. of W., t altitude 6½°, 37 S. of W.
19	6 5 p.m.	Worting, Basingstoke, Hants.	A wonderful light, of the size and form of an egg.	………………	………………	………………………
19	9 45 p.m.	Hawkhurst, Kent	A large and bright head.	Red …………	2 or 3 seconds	From 10° W. o S., altitude 28° to 50° W. of S. altitude 18° where th meteor disap peared behin obstacles.
19	9 45 p.m.	Worcester ……	Sudden bright light; brilliant ball of light.	………………	Rapid ………	In the S.E. ……..
19	About 10 13 p.m.	Gedling, near Nottingham (3½ miles E. of Nottingham).	Exceedingly bright; so bright as to obliterate all the stars and Mars (which was very near to it); it gave as much light as the brightest flashes of lightning.	Colour bright blue, purple, and crimson, the train being of the same colours.	Slow in movement; duration about or under two seconds, and the middle of the train lasting two secs. more after the meteor itself had vanished.	From S.E. by S. t S. by E. Whe first seen, th meteor was pass ing near γ Pegasi it ended near Aquarii.
19	10 13 p.m.	Beeston, near Nottingham.	Not above half the size of the moon.	Exceedingly bright; as light as day; colour vivid blue and reddish.	Slow…………	From 40° abov S.E. by S. ho rizon to abou 20° to 25° abov S. by E. horizon the same mete as above.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
None				J. MacDonald.
				Id.
Somewhat the appearance of a rocket; it appeared to explode, leaving a train of sparks behind it for some seconds.		It proceeded in a northerly direction [?].	The sun, though nearly setting, was shining brightly; not a cloud.	W. S. Tomlin; 'Evening Standard,' Sept. 23rd.
Left no tail; burst into several pieces.		N.E. to S.W.; considerably inclined downwards.	In clear blue sky; before sunset.	Frederick Reeves.
Left a luminous train of blended colours like the rainbow, orange and blue.		Proceeded in a south-westerly direction.	Cloudless sky	
A track of sparks pursued the head but did not endure.		In the S.W., from E. to W.		Communicated by A. S. Herschel.
Seemed to burst, and left a trail of sparks which gradually disappeared in about a minute.		Fell rapidly towards the earth.	Wind E. or N.E.; clear sky, not a cloud.	Correspondent to the 'Standard.'
No definition of shape; a train left in its track; the meteor itself separated into balls, but close together.			A cloudless night	The Rev. S. K. Swann, M.A., F.R.A.S.
Train in track; burst into separate balls.				S. Watson.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862. Sept. 19	h m 10 13 p.m.	Euston Square, London.	Amazing meteor; head = full moon; light = noonday.	Head ruddy; the other extremity and the diffused light blue.	20 seconds ...	Formed an endu ing cloud c sparks overhead R. A. 22^h 30 The strea passed δ, ε, ζ Cephei to R. A. 17 50^m. Both declination 48 20′ N.; mai head procede N.W. by N. fragment S.E.
19	10 13 p.m.	Brentford.........	Gave more light than the brightest lightning.	....	....	Traversed a direc tion slightly S.W
19	10 15 p.m.	Edinburgh (Greenlaw Barracks).	Completely lighted up the road.	The extremity decided blue.	....	Nearly S.E. ....
19	10 15 p.m.	Dullingham Hill, near Dullingham House.	A brilliant meteor in the atmosphere.	Bright light of a bluish cast.	20 secs. from first flash to explosion.	Slanting down wards from E. t W.
19	....	Hay (S. Wales)..	Diffused light; superior to full moon; subsided gradually. (Head like the moon, but much brighter; second observer.)	Diffused light, had a yellowish cast.	2 or 3 seconds duration of brightness.	(Appeared to ascend, turn ove to the righ under α and Arietis, and descend almos vertically; second observer.) Strea passed at brightest par between α and Ceti.
19	....	Bristol, Gloucestershire.	Meteor of unusual size and brilliance; shed much light.	Body rich blue; at explosion showed red and blue colour.	....	In the north-eastern sky it exploded a fe degrees abov the horizon.
19	10 15 p.m.	Weston-super-Mare.	As large as the moon, but much brighter; noticed by candle-light with closed blinds.	....	3 seconds......	From due E. altitude 28°; to N.E altitude 20°.
19	10 15 p.m.	Hawkhurst, Kent	....	....	2 to 3 seconds	Would have met th horizon 15° further on its path at 66° W. from N

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Circular; appeared to separate overhead; the northern head red, emitting prismatic sparks, and leaving a streak of 45° visible eleven minutes at place of bursting. Other extremity, or fragment, blue; disappeared gradually.	....	Vertical from overhead..	Tail broken at intervals, zigzag. Patch overhead circular; 1° diameter; visible 11 minutes; not resolved by power 120 with an aperture of 10in., 20ft. focal length refractor, which resolves the cluster of Hercules freely.	T. Slater; T. Crumplen; J. Townsend.
Globular, then rapidly egg-shaped; then elongating itself and gradually disappearing from view. Track ribbon-like, yellow overhead, the rest blue; endured some minutes.	....	....	First seen directly overhead.	S. Richards, Jun.
Exceedingly beautiful meteor, presenting a sudden and bright light.	?	?	....	W. L. B. Coulson.
Splendid meteor, rushing through the air, and at last bursting vertically downwards into many pieces the size of two-shilling pieces.	....	....	It appeared one hundred yards high when it burst.	Writer in the 'Cambridge Chronicle.'
A bright streak seen on turning round; glowing intensely at the lowest part; fading quickly; a small cloud of sparks remained at last, near ξ Ceti.	....	A little inclined to vertical; downwards towards the right.	....	Rev. T. W. Webb.
Carried in its track a line of ruby-coloured fire; it exploded.	....	....	....	Paragraph in the 'Bristol Mercury.' P. S. Hamlyn.
Numerous prismatic sparks and a yellow tail accompanied the meteor; the latter remained visible two minutes.	....	....	....	Communicated by W. H. Wood.
A stream of fire moving forward; no explosion; disappeared gradually.	63°	Inclined 70° to the horizon; downwards to left.	Path appeared rectilinear.	Communicated by A. S. Herschel.

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Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862. Sept. 19	h m 10 15 p.m.	Wellington, Somerset.	=4 times ♃, or 10 times Sirius.	Body and train blue.	Lasted several seconds.	From ζ Persei to Aurigæ.
19	About 10 20 p.m.	Ipswich	Illuminated every object.	....	....	....
19	10 30 p.m.	Norwich	....	Yellow	?	From S. toward the W.
19	About 10 30 p.m.	Thetford	Lighted up the town like the noonday sun.	Most brilliant colours.	....	....
19	....	London Wall, London.	Entirely lighted up the road.	?	?	Rectilinear in direction; movin N.
19	....	West End, London.	Diffused light; brighter than full moon.	Diffused light, a fine blue.	Disappeared in a few seconds, leaving all as dark as before.	A few degrees E of the zenith.
19	....	Torquay (the Pier).	....	....	Flash 1 sec.; seen in motion 1 sec.	From 9° N. of E altitude 23°; t 27° N. of E altitude 20°.
19	....	Nottingham........	....	....	....	Streak remained parallel to the Ecliptic, from χ Aquarii to τ Piscium.
19	....	London	....	....	....	....
19	....	Enfield Highway, London.	Diffused light, equal to noonday.	Diffused light of a pale violet colour.	....	In a line, but very few degrees S of the zenith An explosion must have taken place but slightly removed from the zenith.

ppearance ; Train, if any, and its Duration.	Length of Path.	Direction ; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	Descended towards N.W. or N.E.	No report heard	W. A. Sanford.
Like a sudden discharge of fireworks. The flame burst suddenly, throwing out brilliant sparks like a rocket; the long tail of white light endured two or three seconds and then gradually faded away.	....	....	....	Paragraph in the 'Ipswich Express.'
Its trail was like a rocket's; its light a bright yellow, and when it burst, a multitude of sparks appeared to fall from the body.	....	....	An explosion was heard at Norwich like that of a rocket in the air.	Correspondent to the 'Norwich Mercury.'
The meteor presented an extraordinary blaze of light, likened to a long tube of fireworks lighted at both ends, each of which in turn broke into smaller sparks.	....	....	....	Writer in the 'Norwich Mercury.'
Brilliant stream of fire like rocket-tail; left a luminous track visible many seconds.	(25°)	Flight longer than the 7 Northern stars.	No such meteor seen in London for ten years before.	Correspondent to the 'Times.'
Track of fire remained like trail of a rocket, showing that a meteor had passed overhead.	....	Mean direction from N. to S.	....	Writer in the 'Times.'
....	....	....	....	Dr. E. Burder.
Streak remained	....	....	....	....
Train preserved an illuminating power for nearly a minute, and then faded gradually away.	....	....	An observer considered it to be an unusual flash of lightning, as bricks could be counted on a wall sixty yards distant.	James Edmunds.
Immense streak appeared in the sky. Bright pale violet at west end, but changing through red to vermilion and carmine in the rest of the path, until lost in the sky.	....	W. to E.; perfectly horizontal from Milky Way to the planet Mars.	....	Ellis Hall.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862. Sept. 24	h m 8 15 p.m.	Broadstairs, Kent	Venus at its brightest, or somewhat brighter.	Blue	2 seconds......	Entered the Mi Way from left, and dis peared a lit below α Aquil
25	6 15 p.m.	Weston-super-Mare.	Much larger than Venus; very splendid meteor.	Red	5 to 8 seconds	Appeared due altitude 26 disappeared S. altitude 18°.
25	6 15 p.m.	Ticehurst, Sussex	As large as a cricket-ball.	Green nucleus within a red envelope.	2 or 3 seconds	From altitude 4 to altitude 15 a little S. the point sunset.
25	6 15 p.m.	Lamberhurst, Sussex.	Large and bright...	....	....	Appeared 60° from S., al tude 40; disa peared due W altitude 20°.
25	6 30 p.m.	Weston-super-Mare.	Larger than Venus	White, with blue tint.	3 seconds......	From 15° N. of the zeni to altitude 40 S.W.
25	6 30 p.m.	Stonyhurst	= Sirius	....	....	Inclined at a angle of 50° t the horizon disappeared at height of 10° o 11° above th horizon.
25	6 35 p.m.	Oxford	....	....	Nearly 10 secs.	....

I. Meteor, 1861, July 16th, 10ʰ 15ᵐ P.M. G.M.T.

By Mrs. E. Addison, of Gainsford, Durham, this meteor was first seen 29° from the horizon, in the direction of the towns Dunkirk or Ostend, upon the Greenwich latitude. Mr. J. Howe, of Greenwich, observed the meteor to pass within 8° or 9° of his zenith, as may be inferred from the position of α Lyræ at the time of the meteor's appearance; but this is at variance with the accounts of Mr. Charles Reed at Westminster, and Mrs. Davies at Southborough, who describe the meteor in the E. as far from vertical. If we assume the meteor to have passed over Dunkirk at an altitude of 30°, as seen from Gainsford, its height was here 172 miles above the French coast. The obstruction of houses on the west side of Whitehall in Mr. Charles Reed's account, shows the meteor to have disappeared nearly due N. from London, at an altitude of 10°, pointed out by Mr. Howe at Greenwich. At Gainsford,

earance ; Train, if any, and its Duration.	Length of Path.	Direction ; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
A slight tail of red sparks pursued the head.	20°	At right angles to the Milky Way.	....	K. E. Rufenacht.
A magnificent meteor ; nucleus surrounded by a halo, and attended by a short train of sparks ; disappeared without sparks.	....	....	The sun had not quite gone down at the appearance of this meteor.	Communicated by W. H. Wood.
Disappeared in the open sky ; globular ; no sparks ; enveloped in a faint light.	....	Vertically down	α Lyræ appeared 30° from its point of commencement.	Rev. F. Howlett.
No tail or sparks...........	....	Inclined downwards from left to right.	....	H. Moreland.
Disappeared gradually without sparks.	....	....	....	Communicated by W. H. Wood.
Brilliant, although the twilight was sufficient to read by.	7° or 8° ...	E. to W.	I was prevented from observing the beginning of its path by a projecting building near the window at which I was sitting.	J. Moore.
In first part of its descent the tail lengthened, but just before its disappearance, collapsed and gathered itself into the nucleus, rendering that much larger and brighter.	....	N.N.E. to S.S.W. ; fell downwards.	....	H. S. C., Correspondent to the 'Standard.'

the same point of the path had altitude 20° in due N.E. The latter lines of sight approach within eleven miles of each other, eighty-eight miles due E. of Newcastle, and forty-four miles above the sea. It is probable, from the account of Mrs. Davies, that the meteor first appeared somewhat S. of the latitude of Dunkirk, and that the entire path of 395 or 400 miles was performed in not less than ten to twelve seconds of time.

II. Meteor, 1861, July 16th, 11^h 32^m P.M. G.M.T.

A similar comparison of the catalogued accounts of this meteor assigns its path with somewhat greater certainty at 300 miles of length, from 195 miles over North Foreland to sixty-five miles above the sea, sixty miles S. of Plymouth. The meteor passed the Isle of Wight at a height of 150 miles ; and here a durable tail first began to be developed from the nucleus. The duration of the flight was five to six seconds, at the largest estimation.

Meteor, 1861, August 6th, 11^h 21^m P.M. G.M.T.

The accounts of Mr. Joseph Baxendell at Manchester, and Messrs. T. Crumplen and J. Townsend at London, determine the centre of this meteor at eighty miles above a point halfway between Leicester and Birmingham; and, assuming its course to have been direct upon Manchester, a path of 176 miles in five seconds is inferred, from 126 miles above Winchester to twenty-one miles above the northern point of Staffordshire.

Shooting-stars, August 8th, 10th, and 11th.

	Time. h m	Appearance.	Place of Centre.	Direction of Flight.	Length of Flight.	Velocity of Flight.	Brilliance.
A.	1861. Aug. 8, 10 31¾ p.m. G.M.T.	A second-magnitude star.	67 miles over Sandhurst (Kent).	From alt. 46°, 3° N. of E.	20 miles (approx.).	30 miles a second (approx.).	At 352 yards would have shown like full moon.
B.	„ „ 8, 10 34 „ „	A flash; first-magnitude.	50 miles over Bury St. Edmunds.	Nearly vertical; down.	6 miles.		At 398 yards „ „ „
C.	„ „ 10, 10 27 „ „	Fine tailed shooting-star; first-magnitude star.	20 miles E. of N. Foreland; 47 miles over the sea.	From alt. 38°, 48° N. of E.	35 miles (approx.).	30 miles a second (approx.).	At 692 yards „ „ „
D.	„ „ 10, 10 50½ „ „	Third-magnitude star.	70 miles over Leatherhead.	From alt. 54°, 20° N. of E.	20 miles (approx.).	30 miles a second (approx.).	At 274 yards „ „ „
E.	„ „ 11, 10 20 „ „	Bright white-tailed shooting-star, and equal to Venus.	70 miles E. of Ipswich; 32 miles above the sea.	From alt. 42°, 70° N. of E.	36 miles.	27 miles a second.	At 1484 yards „ „ „

Meteor, 1861, November 12th, 5^h 49^m P.M.

The accounts of Mr. L. and Mr. W. Penn at Oxwich and Stone, place the earliest appearance of this meteor at 90 to 100 miles over Peterborough or Cambridge. Its approach to the zenith, both at Hay and at Bristol, indicates a passage between the latter stations; and the remaining accounts will be found to be satisfied with considerable accuracy by a course of sixty miles above Lundy island, terminated with a slight dip towards the sea, and explosion twenty miles above it, upon the meridian of Land's End. The flight of 360 miles appears to have occupied seven or eight seconds of time.

Meteor, 1861, November 15th, $10^h\ 14^m$ P.M.

The meteor described by Mr. Nash at Greenwich, and Mr. Herschel at Shooter's Hill, although identical, do not admit of useful comparison with one another, nor with that observed by Mr. Greg at Styall, near Manchester,—the base-line in the former case being too small for such a purpose, and the third meteor being apparently distinct from the former two.

Meteor, 1861, November 19th, $9^h\ 38^m\ 30^s$ P.M.

The Ipswich and Norwich accounts place the audible explosion of this brilliant meteor at no great height between the two towns; thirty miles of height must be allowed to it for the altitude as seen from Exeter, although such a height is at variance with the view obtained from Greenwich and North Foreland. It is not impossible that explosion, audible at Norwich and Ipswich, and perhaps also at North Foreland, may have depressed the last portion of the flight, for this was hidden from view at Exeter. The near verticality at North Foreland, the passage over the moon (whose altitude was 38° E. by S.) in the eastern parts of Kent, and the low southern position of the nucleus as first perceived by Messrs. Hill at Woodford, Mitchell and Harmer at Tunbridge, and James Rock, jun. at Guestling, show this meteor to have taken a nearly meridian and nearly horizontal course. A flight of 260 miles in 10 or 12 seconds, from fifty-five miles above Paris to thirty miles above Beccles (between Suffolk and Norfolk), is found to satisfy the whole of the accounts with considerable accuracy.

Meteors, 1861, November 24th, $8^h\ 0^m$ P.M.

The resemblance of these meteors is casual,—the lines of sight of commencement lying widely upon opposite sides of the base-line between the stations, while those of termination approach no nearer than twenty-six miles upon the southern side of the base-line.

Meteors, 1861, December 1st, $9^h\ 15^m$ P.M.

The resemblance of these meteors is not borne out by the uranographical positions assigned to them at the two distant stations,—the point of commencement having little or no parallax with considerable deviation of the lines of sight, while the lines of sight of termination lie upon opposite sides of the base-line.

Meteor, 1861, December 8th, $8^h\ 16^m$ P.M.

At Dungannon in Ireland this meteor appeared to fall vertically, while at Wakefield (Yorkshire) it passed overhead. The observation of Dr. Walker at Birkenhead (Seacombe), assigns Strangford, on the Irish coast, as the spot between these two towns where the body would have struck the earth. By Mr. Redford's account, from Silloth near Carlisle, the height at disappearance is found to be fifty miles above the sea, halfway from Lancaster to the Isle of Man; the height above Wakefield eighty-five miles, and at Hull 110 to 115 miles. Modified by the remaining accounts, a course of 160 miles from 110 miles above Hull to forty-five miles above the Irish Sea, twenty miles E. of Douglas Town, performed in six or eight seconds of time, appears to be a near approximation to the truth. It is possible that an explosion loudly heard at Lancaster and Southport, but not heard at Douglas, may have caused the deflection by which the meteor in the latter portion of its flight appeared stationary at Castletown some seconds. On the 3rd of the same month, a similar detonating meteor appeared in Germany, bursting sixty miles over Dessan, and directed almost from the Pole (see the Calculation of Professor Heis). Mr. Greg at this time observed the radiant point of shooting-stars to lie between Gemini and Auriga. On the 24th of December it was in Taurus.

Meteors, 1861, December 9th, 5^h 30^m P.M.

The resemblance is casual. The uranographical position at Hawkhurst places this meteor at a great height towards Edinburgh, upon the latitude of Glasgow.

Shooting-star (F), 1862, January 28th, 11^h 4^m P.M.

The base-line of forty miles between the stations of London and Stone affords a good determination of this shooting-star. The lines of sight for the commencement are only three miles apart at their nearest approach, namely, at 44½ miles above Melton Mowbray in Leicestershire, while those of termination are only 2½ miles asunder at 47½ miles above Macclesfield in Cheshire. The horizontal flight of sixty miles was performed in 1⅓ to 1½ second, by careful estimation at the time of the observation. Direction from 32° S. of E. At 880 yards it would have equalled the full moon.

Meteor, 1862, February 2nd, 8^h 20^m P.M.

The astronomical accounts of Mr. E. J. Lowe and Mr. Alcock at Beeston Observatory and Newark, together with similar details from Tarporley in Cheshire, appear to fix the disappearance of this meteor with precision at fourteen or fifteen miles above Cheadle, on the borders of Derbyshire, where the meteor arrived after a flight in the air of 236 miles from 190 miles above Lyme Regis, occupying six seconds of time and directed to earth in the valley of the Dove, or at the foot of the Peak of Derbyshire. The point of first appearance in Orion or the Pleiades, as seen at Liverpool and Tarporley, places this meteor among the few whose true courses are observed to lie from W. to E. of the meridian.

Meteor, 1862, February 23rd, 9^h 25^m P.M.

This meteor, which passed nearly over Liverpool towards S.W., appeared to Mr. W. H. Wood, at Weston-super-Mare, to move 30° horizontally in the N. at 20° from the horizon. It appears to have sought the earth at Pembroke, and had its flight from forty miles above Stockport, near Manchester, to twenty miles above Aberystwith, in Wales.

The following comparison of the brightness of these meteors is offered as leading to an estimation of their probable dimensions.

The photometric tables of the light of certain stars compared with that of the full moon, published by Sir John Herschel, enable us to compare the light of ordinary shooting-stars with a standard generally familiar; and the same may be done when fireballs are compared in their illuminating power to different phases of the moon; but the class of meteors intermediate between these in the scale of brilliancy are usually compared with the planets of whose light at different phases no tables are prepared. Among the preceding known meteors, one only of the latter class (shooting-star ϵ) is found. The following deductions aim at no greater accuracy than is commensurate to the character of the observations themselves.

(A) I. Meteor, 1861, July 16th, 10^h 15^m P.M.: shone apparently as half of a moon two days old, at Furness, 150 miles from the meteor's termination. *At 25½ miles it would have equalled the full moon.*

(B) II. Meteor, 1861, July 16th: shone as one-fourth of moon two days old, at Flimwell, distant 220 miles from bursting. *At 37½ miles it would have equalled full moon.*

(C) Meteor, 1861, August 6th, 11^h 21^m P.M.: shone one-tenth of moon two days old, at London, 150 miles from brightest point. *At eight miles it would have equalled full moon.*

Shooting-stars, August 8th, 10th, 11th, would have equalled full moon at distance of 352, 398, 692, 274, 1484 yards.

(D) Meteor, 1861, November 12th, 5^h 49^m P.M.: lighted the turnpike-road at Hay fully as much as the moon itself shining upon it, and ten days old. Meteor overhead, seventy-five miles from Hay. *At sixty-three miles it would have equalled full moon.*

(E) Meteor, 1861, November 19th, 9^h 38^m P.M.: threw shadows half as deep as the moon, then full, at Tunbridge, seventy-seven miles from the first burst of light. *At fifty-four miles it would have equalled full moon.*

(F) Meteor, 1861, December 8th, 8^h 16^m P.M.: exceeded the light of the moon then shining clear and six days old, at Hull, 130 miles from the flash over Walney Isle. *At eighty-eight miles it would have equalled full moon.*

(G) Meteor, 1862, February 2nd, 8^h 20^m P.M.: shone as brightly as the moon unclouded and ten days old, at Beeston, forty miles from the explosion. *At thirty miles it would have equalled full moon.*

(H) Meteor, 1862, February 23rd, 9^h 25^m P.M.: threw a bright light from the sky which filled the streets at Liverpool and Bromborough, distance forty miles; perhaps equal to a moon four days old. *At 16½ miles it would have equalled full moon.*

Assuming an ordinary flame of street gas to measure a cubic inch of incandescent matter, and at 15 yards to throw a light equal to the direct light of full moon, we have 13,690 gas flames at a mile equivalent to full moon; and the following are the globes of burning coal-gas which would shed the light produced by the separate meteors and shooting-stars of the foregoing list.

Meteors.	I. July 16.	II. July16.	Aug. 6.	Nov. 12.	Nov. 19.	Dec. 8.	Feb. 2.	Feb. 23.
Diameters of burning globes.	ft. in. 21 8	ft. 28	ft. 10	ft. in. 39 6	ft. in. 35 9	ft. in. 49 5	ft. 24	ft. in. 14 3

Shooting-stars.	A.	B.	C.	D.	E.	F.
Diameters of incandescent globes.	in. 10·2	in. 11·1	in. 16·1	in. 8·7	in. 26·7	in. 14·0

It is possible that these results afford a juster idea of the real sizes of the luminous bodies than those derived from angular measurements of their apparent discs.

[For Errata of the Catalogue, &c., see Appendix I. at the end of the Reports in this volume.]

On the Strains in the Interior of Beams.

By GEORGE BIDDELL AIRY, *F.R.S., Astronomer Royal.*

[A communication ordered to be printed among the Reports.]

THE author states that he had long desired to possess a theory which should enable him to compute numerically the strains on every point in the interior of a beam or girder, but that no memoir or treatises had given him the least assistance*. He had therefore constructed a theory which solved completely the problems for which he wanted it, and which appears to admit of application at least to all ordinary cases.

The theory contemplates forces acting in one plane. A beam therefore is considered as a lamina in a vertical plane, the same considerations applying to every vertical lamina of which a beam may be conceived to be composed.

The author remarks that it is unnecessary to recognize every possible strain in a beam. Metallic masses are usually in a state of strain, from circumstances occurring in their formation; but such strains are not the subject of the present investigation, which is intended to ascertain only those strains which are created by the weight of the beam and its loads. The algebraical interpretation of this remark is, that it is not necessary to retain general solutions of the equations which will result from the investigation, but only such solutions as will satisfy the equations.

After defining the unit of force as the weight of a square unit of the lamina, and the measure of compression-thrust or extension-pull as the length of the ribbon of lamina, whose breadth is the length of the line which is subject to the transverse action of the compression or tension, and whose weight is equal to that compression or tension, the author considers the effect of tension, &c. estimated in a direction inclined to the real direction of the tension, and shows that it is proportional to the square of the cosine of inclination. He then considers the effect of compounding any number of strains of compression or tension which may act simultaneously on the same part of a lamina, and shows that their compound effect may in every case be replaced by the compound effect of two forces at right angles to each other, the two forces being both compressions or both tensions, or one compression and one tension. Succeeding investigations are therefore limited to two such forces.

Proceeding then to the general theory of beams, it is remarked that if a curve be imagined, dividing a beam into any two parts, the further part of the beam (as estimated from the origin of coordinates) may be considered to be sustained by the forces which act in various directions across that curve, taken in combination with the weight of the further part of the beam, the load upon that part, the reaction of supports, &c. Expressing the forces in conformity with the principles already explained, and supposing that there is one compression-force B making an angle β with y (in the direction of y diminishing for increase of x), and another compression-force C making an angle $90°+\beta$ with y, it is easily seen that the element δs of the curve, supposed to make the angle θ with y, sustains the forces

$$\text{In } x,\quad \mathrm{B}\,.\,\delta s\times\sin(\beta+\theta)\times\sin\beta+\mathrm{C}\,.\,\delta s\times\sin(\beta+90°+\theta)\times\sin(\beta+90°).$$

$$\text{In } y,\, -\mathrm{B}\,.\,\delta s\times\sin(\beta+\theta)\times\cos\beta-\mathrm{C}\,.\,\delta s\times\sin(\beta+90°+\theta)\times\cos(\beta+90°).$$

The weight of lamina bounded by y and $y+\delta y$, and estimated as acting upwards, is $-y\delta x$. And the reaction R of a support may act upwards at distance h.

---

* Subsequently to the communication of this Report, the author learned that one instance (the second) of those given here had been treated by Professor Rankine, by methods peculiar to that instance.

Expanding the sines and cosines, putting δx for $\sin\theta\,.\,\delta s$, and δy for $\cos\theta\,.\,\delta s$; putting also

$$\begin{aligned}
&L=B\,.\sin^2\beta+C\,.\cos^2\beta,\\
&M=(B-C)\,.\sin\beta\,.\cos\beta,\\
&Q=-B\,.\cos^2\beta-C\,.\sin^2\beta,\\
&O=y-Q,\\
&p=\frac{dy}{dx},
\end{aligned}$$

and forming the equations of equilibrium in the usual way, they will be found to be—

Equation for forces in x, $\int dx\,.(Lp+M)=0.$

Equation for forces in y, $\int dx(Mp+O)-R=0.$

Equation of momenta, $\int dx(Lyp+My+Mxp+Ox)-Rh=0.$

Now these equations, applying to any curve, will apply to any two curves very close together; and therefore their variation, taken by the rules of the Calculus of Variations, will be 0. The proper equation (in the usual notation) is $N-\frac{d(P)}{dx}=0$. Applying this, the results are

$$\frac{dM}{dy}-\frac{dL}{dx}=0,$$
$$\frac{dO}{dy}-\frac{dM}{dx}=0.$$

From this it follows that (omitting some arbitrary functions which represent original strains in the formation of the beam) L, M, O, are partial differential coefficients of the same function of x and y, which we may call F: so that

$$L=\frac{d^2F}{dy^2},\quad M=\frac{d^2F}{dxdy},\quad O=\frac{d^2F}{dx^2}.$$

Substituting these, the equations become

$$\int.\,d\left(\frac{dF}{dy}\right)=0,\quad \int.\,d\left(\frac{dF}{dx}\right)-R=0,\quad \int.\,d\left(y\frac{dF}{dy}+x\frac{dF}{dx}-F\right)-Rh=0.$$

Considerations, of a somewhat detailed character, depending partly on the relation assumed to exist between tension-force and material extension, are necessary to show the form which must be assumed for F in the various cases to be examined. The conditions to be secured are—that the horizontal part of the thrust, &c. shall be the same as that given by ordinary theories, on the relation just mentioned; and that the equations above shall be satisfied. After due application of these in the following five cases, these forms are found for F.

Case 1. A beam of length r and depth s projecting from a wall;

$$F=\frac{6}{s^3}\,.\,(r-x)^2.\left(\frac{sy^2}{4}-\frac{y^3}{6}\right).$$

Case 2. A beam of length $2r$ and depth s supported at both ends;

$$F=\frac{6}{s^3}\,.\,(x^2-2rx)\,.\left(\frac{sy^2}{4}-\frac{y^3}{6}\right).$$

Case 3. A beam like the last, carrying a weight W at the distance a from one end.

In this case the function is discontinuous; its forms are—

From $x=0$ to $x=a$, $F=\frac{6}{s^2}\left\{\left(2r+W\frac{2r-a}{rs}\right)x-x^2\right\}\cdot\left(\frac{y^3}{6}-\frac{sy^2}{4}\right)$.

From $x=a$ to $x=2r$, $F=\frac{6}{s^2}\cdot\left\{\frac{2Wa}{s}+\left(2r-W\frac{a}{rs}\right)x-x^2\right\}\cdot\left(\frac{y^3}{6}-\frac{sy^2}{4}\right)$.

(Of this case, two instances are given in the curves below.)

Case 4. A beam like that in Case 2, with a straining momentum applied at each end, as in the middle tubes of the Britannia Bridge;

$$F=\frac{6x^2-12rx+3r^2}{s^2}\left(\frac{sy^2}{4}-\frac{y^3}{6}\right).$$

Case 5. A beam like that in Case 2, with a straining momentum applied at one end only, as in the exterior tubes of the Britannia Bridge;

$$F=\frac{(6x-12r)\left(x-\frac{r}{4}\right)}{s^2}\left(\frac{sy^2}{4}-\frac{y^3}{6}\right).$$

By forming the differential coefficients of F symbolically, L, M, and Q $(=y-O)$ are obtained in a form which admits of numerical calculation for every value of x and y. And from these, B, C, and β are computed without difficulty.

In this way the values of B, C, and β have been found for every combination of the values $x=r\times 0{\cdot}1$, $x=r\times 0{\cdot}2$, $x=r\times 0{\cdot}3$, &c., with the values $y=s\times 0{\cdot}1$, $y=s\times 0{\cdot}2$, $y=s\times 0{\cdot}3$, &c. In Case 1, 121 points were thus treated: in each of the other cases the computations were made for 231 points.

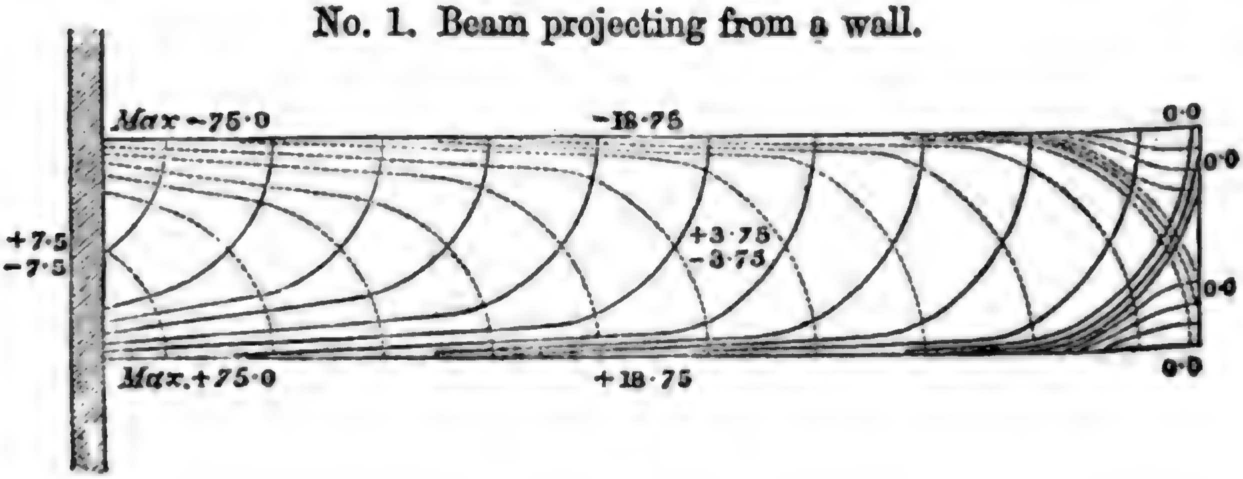
In the following diagrams are given the curves representing the directions of pressure and tension through the beam, together with a few numerical values at the most critical points, for each of the cases to which allusion has been made.

CURVES REPRESENTING THE STRAINS IN BEAMS, UNDER DIFFERENT CIRCUMSTANCES.

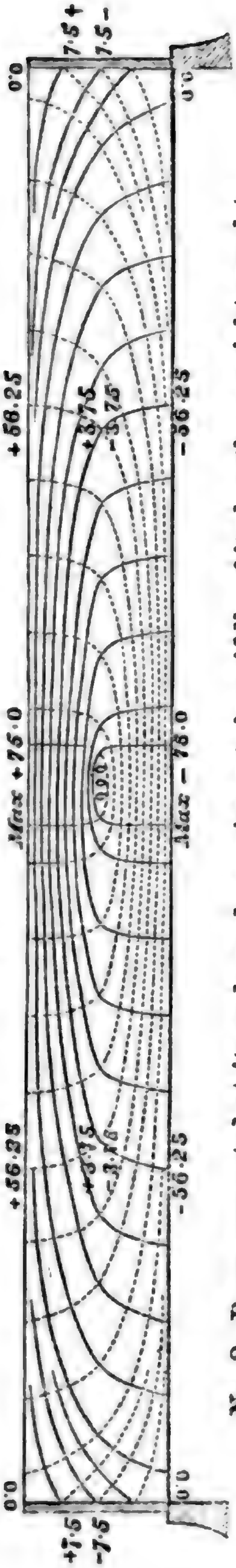
The continuous curves indicate the direction of thrust or compression; the interrupted curves or chain lines indicate the direction of pull or tension.

The figures denote the measure of the strain; the sign + meaning compression, and − meaning tension. The unit of strain is the weight of material lamina whose length = depth of beam.

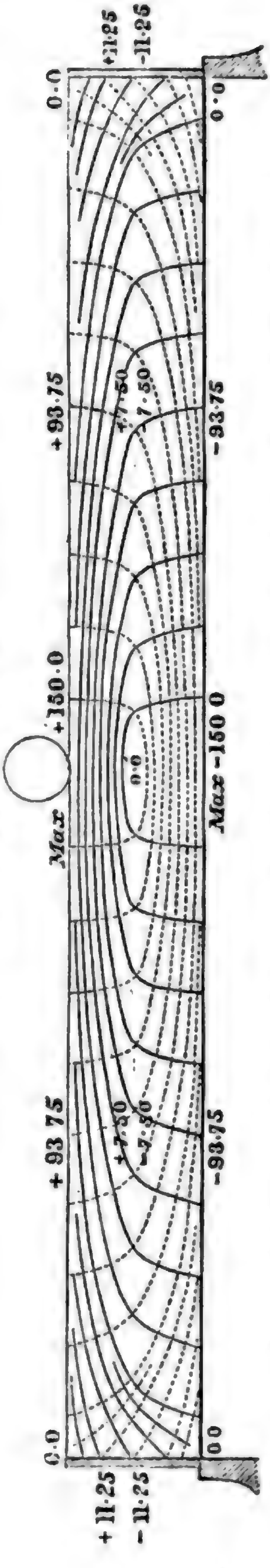
No. 1. Beam projecting from a wall.



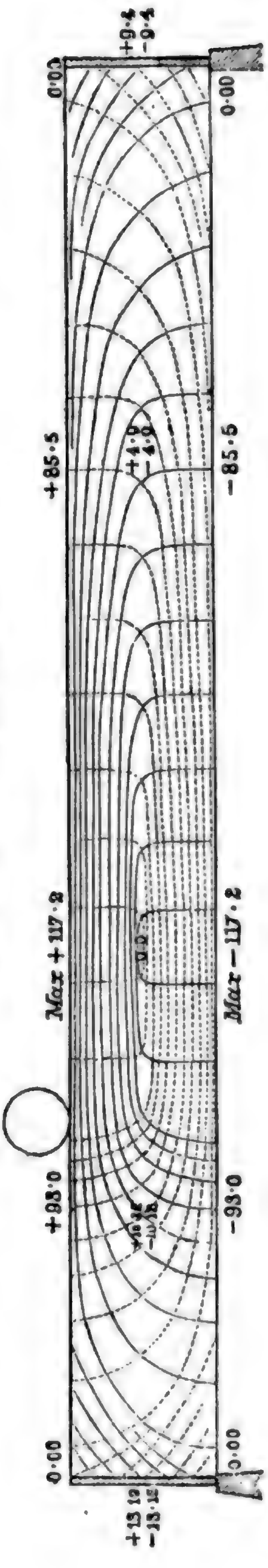
No. 2. Beam supported at its ends.


0·0
+56·25
Max +75·0
+56·25
0·0
+7·5
−7·5
+3·75
−3·75
0·0
+3·75
−3·75
7·5+
7·5−
0·0
−56·25
Max −75·0
−56·25
0·0

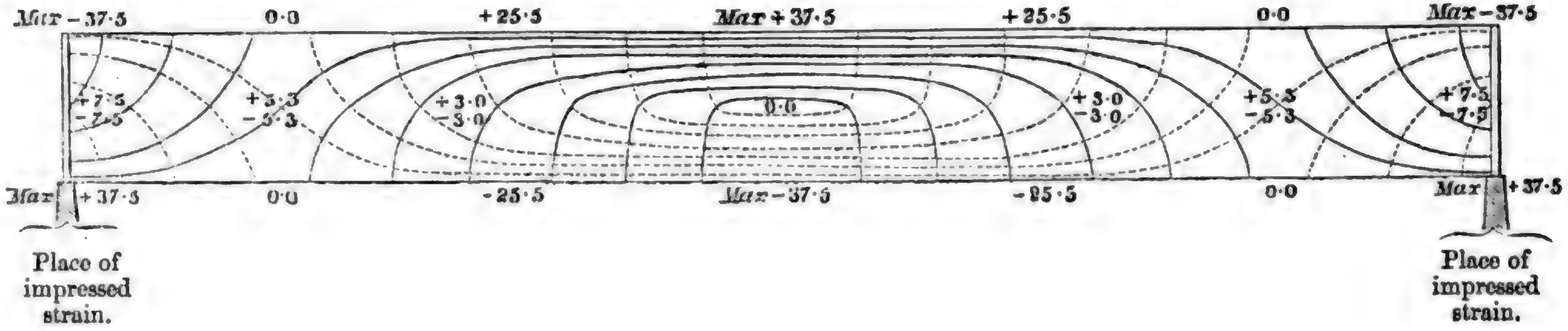
No. 3. Beam supported at its ends, and carrying, at the middle of its length, a weight equal to half the weight of the beam.


0·0
+93·75
Max +150·0
+93·75
0·0
+11·25
−11·25
+7·50
−7·50
0·0
+7·50
−7·50
+11·25
−11·25
0·0
−93·75
Max −150·0
−93·75
0·0

No. 4. Beam supported at both ends, and carrying, at the middle of a half length, a weight equal to half the weight of the beam.


0·00
+93·0
Max +117·2
+85·5
0·00
+13·12
−13·12
+10·16
−10·16
0·0
+4·0
−4·0
+9·4
−9·4
0·00
−93·0
Max −117·2
−85·5
0·00

No. 5. Beam supported at both ends, and in which a strain (of the nature of a moment or couple) is impressed on each end, as in the interior tubes of the Britannia Bridge.


Max −37·5
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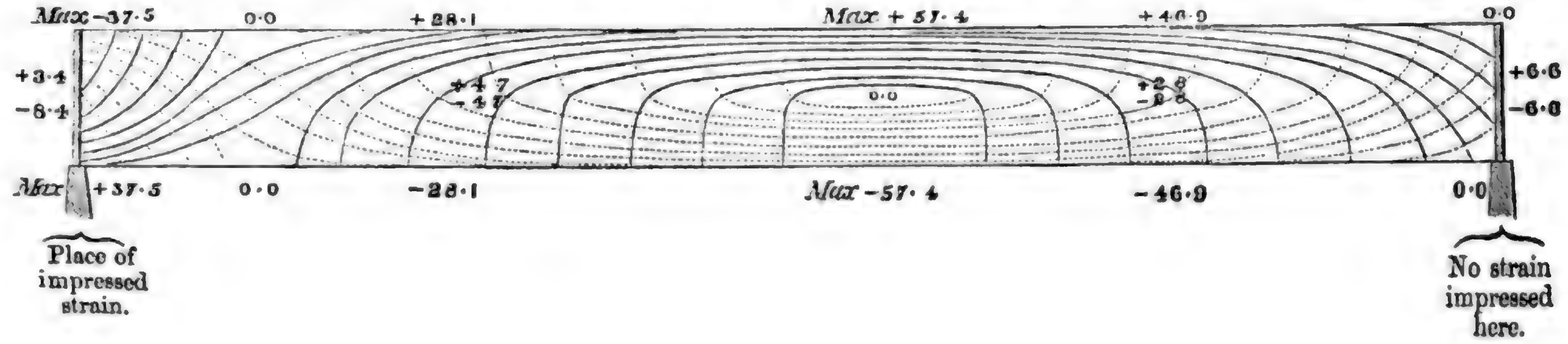
+25·5
Max +37·5
+25·5
0·0
Max −37·5
+7·5
−7·5
+5·3
−5·3
+3·0
−3·0
0·0
+3·0
−3·0
+5·3
−5·3
+7·5
−7·5
Max +37·5
0·0
−25·5
Max −37·5
−25·5
0·0
Max +37·5
Place of impressed strain.
Place of impressed strain.

No. 6. Beam supported at both ends, and in which a strain (of the nature of a moment or couple) is impressed on one end, as in the exterior tubes of the Britannia Bridge.


Max −37·5
0·0
+28·1
Max +57·4
+40·9
0·0
+3·4
−8·4
+4·7
−4·7
0·0
+2·8
−2·8
+6·6
−6·6
Max +37·5
0·0
−28·1
Max −57·4
−46·9
0·0
Place of impressed strain.
No strain impressed here.

Report on the three Reports of the Liverpool Compass Committee and other recent Publications on the same subject. By ARCHIBALD SMITH, *M.A., F.R.S., and* FREDERICK JOHN EVANS, *R.N., F.R.S.*

THE task which we have undertaken, at the request of the British Association, is in some degree lightened by the publication, since the last meeting, of the 'Admiralty Manual for ascertaining and applying the Deviations of the Compass,' a work which has been compiled under our joint editorship, and published by the direction of the Lords Commissioners of the Admiralty. The publication of this work allows us to treat as known, various methods and formulæ which had not previously been published, and to which it will be necessary to refer in the sequel. It, however, makes it necessary that we should give some account of our own work, and this we think it will be most convenient that we should do at the outset.

The 'Manual' is divided into four parts. Part I. contains the well-known "Practical Rules" published by the Admiralty, drawn up originally, in 1842, by a committee consisting of the late Admirals Sir F. Beaufort and Sir J. C. Ross, Captain Johnson, R.N., Mr. Christie, and General Sabine. These rules were, and still are, purely practical,—the object being to enable the seaman, by the process of swinging his ship, to obtain a table of the deviations of his compass on each point, and then to apply the tabular corrections to the courses steered.

Part II. is a description of the valuable graphic method known as "Napier's method," in which the deviations of the compass are represented by the ordinates of a curve, of which the "courses" or azimuths of the ship's head which correspond to the deviations are the abscissæ. These azimuths may be measured either from the "correct magnetic north," in which case they are called the "correct magnetic courses," or from the direction of the disturbed needle, in which case they are called "compass courses;" and we should in general obtain one curve if the abscissæ represent one set of courses, and a different curve if the abscissæ represent the other set. It was, we believe, first observed by Mr. J. R. Napier that, by drawing the two sets of ordinates in proper directions, each may be made to give the same identical curve, and, conversely, that the *same* curve may be made to give the deviations as well on the correct magnetic courses as on the compass courses, with the additional advantage that the one set of courses may be at once derived from the other by going from the axis of abscissæ to the curve, in a direction parallel to one of the sets of ordinates, and returning to the axis of abscissæ in a direction parallel to the other. The original direction of each set of ordinates is arbitrary, the scale, however, depending on those directions. By drawing the ordinates at angles of 60° and 120° from the axis of abscissæ, we have the advantage that the scale along each axis of ordinates and also along the axis of abscissæ is the same; and these directions are in general the most convenient, although in particular cases, as when the deviations are very small, it is convenient to take a larger scale for the ordinates than for the abscissæ. The practical advantages of the method are very great. It enables the navigator, from observations of deviations made on any number of courses, whether equidistant or not, to construct a curve in which the errors of observation are, as far as possible, mutually compensated, and which gives him the deviation as well on the compass courses as on the correct magnetic courses. Various modifications of this method have been proposed, of which one by Capt. A. P. Ryder, R.N., deserves particular mention from the facility with which it may be used by those to whom the method is unfamiliar; but for general use there seems to be no form superior to the usual form of Napier's diagram.

Part III. contains the practical application to this subject of mathematical formulæ derived from the fundamental equations deduced by Poisson from Coulomb's theory of magnetism. This part was published separately in the year 1851, and afterwards as a Supplement to the "Practical Rules" in 1855. At that time it was considered sufficient to use approximate formulæ, going as far only as terms involving the first powers of the coefficients of deviation. The very large deviations found in iron-plated ships of war rendering it desirable to use in certain cases the exact instead of the approximate formulæ, this part has been re-written.

It may be desirable to give here some account of these formulæ.

Poisson's equations are derived from the hypothesis that the magnetism of the ship, except so far as it is permanent, is *transient induced* magnetism, the intensity of which is proportional to the intensity of the inducing force, and that the length of the compass-needle is infinitesimal compared to the distance of the nearest iron.

On this hypothesis the deviation of the compass is represented *exactly* by one or other of the following formulæ:—

$$\sin\delta=\mathfrak{A}\cos\delta+\mathfrak{B}\sin\zeta'+\mathfrak{C}\cos\zeta'+\mathfrak{D}\sin(2\zeta'+\delta)+\mathfrak{E}\cos(2\zeta'+\delta)\ \ldots\ (1)$$

$$\tan\delta=\frac{\mathfrak{A}+\mathfrak{B}\sin\zeta+\mathfrak{C}\cos\zeta+\mathfrak{D}\sin 2\,\zeta+\mathfrak{E}\cos 2\zeta}{1+\mathfrak{B}\cos\zeta-\mathfrak{C}\sin\zeta+\mathfrak{D}\cos 2\,\zeta-\mathfrak{E}\sin 2\zeta}\ \ldots\ldots\ldots\ldots\ (2)$$

in which δ represents the deviation, ζ the "correct magnetic course," ζ' the "compass course;" $\mathfrak{A}$, $\mathfrak{D}$, $\mathfrak{E}$ are coefficients depending solely on the soft iron of the ship; $\mathfrak{B}$ and $\mathfrak{C}$ coefficients each consisting of two parts, one part a coefficient depending on the soft iron and multiplied by the tangent of the dip, the other part a coefficient depending on the hard iron and multiplied by the reciprocal of the earth's horizontal force at the place, and by a factor, $\frac{1}{\lambda}$, generally a little greater than unity, and depending on the soft iron. In these equations the sign + indicates an *easterly*, — a *westerly* deviation of the north point of the compass.

If the coefficients are so small that their squares and products may be neglected, the first equation may be put under the form

$$\delta=\mathrm{A}+\mathrm{B}\sin\zeta'+\mathrm{C}\cos\zeta'+\mathrm{D}\sin 2\zeta'+\mathrm{E}\cos 2\zeta'\ \ldots\ldots\ldots\ldots\ (3)$$

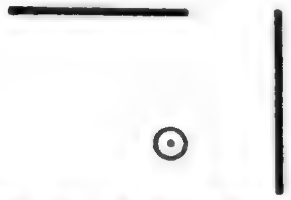
in which it will be observed that the coefficients are now expressed in *arc*, the Roman letters being nearly the arcs of which the German letters are the sines. When the deviations do not exceed 20°, this equation is sufficiently exact.

As the subject with which we are now dealing cannot be understood or followed without distinctly apprehending the meaning of the several parts of this expression, we do not apologise for pausing to explain them.

The term A is what is called the "constant part of the deviation." A *real* value of A can only be caused by *soft* iron *unsymmetrically* arranged with reference to the compass.

It will easily be seen that such an arrangement of horizontal soft iron rods, such as that in figure 1,

Fig. 1.



would give a *positive* value of A, and no other term in the deviation.

A soft iron rod, such as that in figure 2,

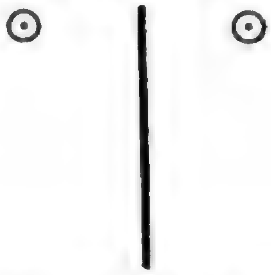


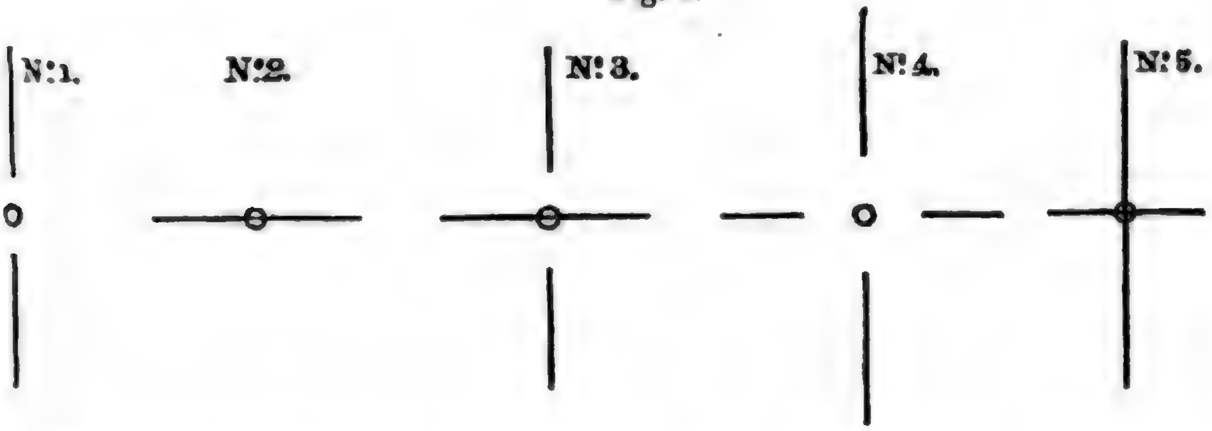
Fig. 2.

would give $+$A to the starboard compass, combined, however, with $+$E; and $-$A, combined with $-$E, to the port compass. The last arrangement is one sometimes found in the relative positions of the horizontal iron spindle of the wheel and the binnacle compasses placed near it. In compasses placed in the midship line of the ship, such unsymmetrical arrangements of soft iron can seldom have any sensible operation. In such cases A is always small; and when it has a sensible value, it seems more likely to arise from index error of the compass, or from error of observation, and may probably be best dealt with as such, and disregarded in the table of deviations.

The terms $B \sin \zeta' + C \cos \zeta'$ make up together what is called the "semicircular deviation." This is the part of the deviation which it is most difficult to deal with, as well from each coefficient being made up of the two parts which we have described, which cannot be distinguished by observations made in one latitude, as from that part of the ship's magnetism, which we have treated as *permanent*, being in fact only *subpermanent*. To this we shall have occasion to revert in the sequel. At present we will only point out that $+$B indicates an attraction of the north point of the compass to the ship's head, $-$B to the stern, $+$C an attraction of the north point to the starboard side, $-$C to the port side.

The terms $D \sin 2\zeta' + E \cos 2\zeta'$ make up what is called the "quadrantal" deviation. This can only be caused by *horizontal* induction in *soft* iron. E can only be caused by horizontal induction in soft iron *unsymmetrically* distributed, and is therefore, except in such cases as those represented in fig. 2, very small. $+$D may be caused by the following arrangements of *symmetrically* arranged soft iron, in which the ship's head is supposed to be directed towards the top or bottom of the page. $-$D may be caused by the same arrangements, the ship's head being now supposed to be directed to the right or left of the page.

Fig. 3.



Between these various arrangements there is this most important difference, that in No. 1 and No. 4 the directive force of the needle would be increased, while in No. 2 and No. 5 it would be diminished. In No. 3 it might be either increased, or diminished, or left unaltered, according as the effect of the longitudinal and the transverse iron preponderated. We may, therefore, by observing the effect on the directive force, as well as on the quadrantal deviation, ascertain how much of the latter is caused by fore-and-aft iron, how much by transverse iron.

This explanation of the coefficients will probably be sufficient for the purposes of this Report, and we now revert to Part III. of the 'Manual.' The principal object of this part is to find the means of computing A, B, C, D, E, from the deviations observed or derived by Napier's curve for a certain number (8, 16, or 32) equidistant points. This is easily done by formulæ founded on the method of least squares; and the method is made of ready application by tabular forms and tables given in this part.

The direct computation of the exact coefficients $\mathfrak{A}$, $\mathfrak{B}$, $\mathfrak{C}$, $\mathfrak{D}$, $\mathfrak{E}$ by the method of least squares would be a matter of very great labour; but they are easily derived to terms of the 3rd order inclusive from the approximate coefficients A, B, C, D, E by formulæ which are given for the first time in this part.

There are two other coefficients, the knowledge of which is of great importance, but which can only be derived from observations of *force*, viz. λ, or the ratio of the mean force to north at the place of the compass to the earth's horizontal force, and μ, the ratio of the mean vertical force at the same place to the earth's vertical force.

One of the most important errors in the modern iron-built and iron-plated vessels is the *heeling error*. The deviations obtained by the usual process of swinging are for a vessel on an even keel. It is found by experience that as the vessel heels to one or other side, the north point of the compass is drawn either to the weather or lee side, generally the former; and the deviation so produced, when the ship's course is near north or south, often exceeds the angle of heel. This not only produces a deviation which may cause a serious error in the ship's course, but if the ship is rolling, and particularly if the period of each roll approximates to the period of oscillation of the compass, produces a swinging of the compass-needle, which may amount to many times the angle of heel, and make the compass for the time useless for steering.

This is a part of the deviation which has been involved in some obscurity. Mr. Airy, in a paper in the 'Transactions of the Institution of Naval Architects,' vol. i. p. 107 (1860), says that the disturbance produced by heeling has not been well observed, and its correction has not yet been reduced to easy laws; and that the effect of heeling is the only part of the magnetic disturbance in regard to which the practical correction of the compass is really at fault; and the Reports of the Liverpool Compass Committee refer to it as one of the most perplexing parts of the subject. It therefore appeared to us desirable to deduce from Poisson's formulæ, expressions for the alteration of the coefficients introduced by the inclination of the ship. This has been done in the 'Manual,' and the result is, we think, to remove entirely the obscurity which rested on the subject. The effect of the heeling error is, as might have been anticipated, to leave unaltered the coefficients which depend on fore-and-aft action, viz. B and D, to alter C, and to give a value to A and E. The latter appear to be, except when the compass is near either extremity of the vessel, of small amount. The alteration of C is the only one which is important. The formulæ show that it consists of two parts, which are caused by arrangements of iron, such as that in the following figure, in which the vertical line represents iron permanently magnetized,

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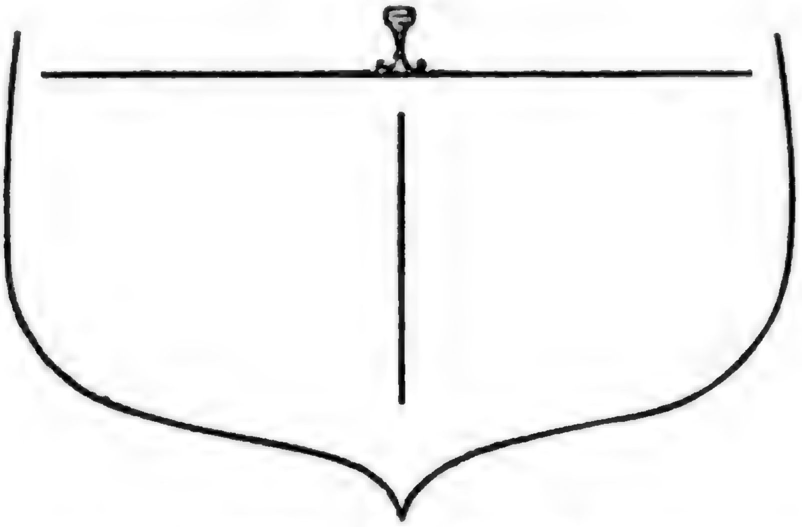
or vertical iron magnetized by induction, drawing the north end of the needle downwards in the northern hemisphere; the horizontal line a rod, such as that in fig. 3, No. 2, which would give +D, and which, when the ship's head is north or south, will have no effect till the ship heels, when its upper (weather) end will attract the north point of the compass. Each rod in the figure will therefore cause a deviation of the north point of the needle to the weather side. In order to correct this, the vertical magnetism must either act upwards. or the transverse magnetism must be such as would be caused by a horizontal transverse rod on each side of the compass, the formula indicating the relation which must exist between the vertical and the transverse horizontal magnetism in order that the heeling error may be zero.

Fig. 4.



The 4th Part of the 'Manual' contains charts of the lines of equal variation, equal dip, and equal horizontal force over the globe; the first for the purpose of enabling the navigator at sea to determine the deviation by astronomical observations; the two latter to throw light on the changes which the deviations undergo on a lengthened voyage, and to enable the navigator to anticipate the changes which will take place on a change of geographical position.

Of the Appendices, one (No. 2) contains a short account of the method proposed by Mr. Airy for the mechanical correction of the semicircular and quadrantal deviation, and a notice of a method lately proposed by Mr. Evans for the correction of the quadrantal deviation when excessive. No. 3 is on the mathematical theory of the deviations of the compass, being the deduction from Poisson's equations of such formulæ as may be most conveniently applied to the analysis of the tables of deviations derived from actual observation.

There is a graphical method of representing the magnetic state of a ship as regards deviation, described in pp. 106 and 107, which we may shortly describe.

If from the centre of a compass, in any part of the ship, we draw a horizontal line, representing in amount and direction the ship's disturbing force on the north end of the needle of that compass, the ends of all the lines so drawn will, as is shown in this appendix, trace out an ellipse. If the soft iron of the ship be symmetrically distributed, so that $\mathfrak{A}$ and $\mathfrak{E}$ are zero, the construction of this ellipse is simplified, as its axes are then parallel and perpendicular to the fore-and-aft lines of the ship. The position of the centre of the ellipse gives the amount of the force to head, and force to side, which cause the semicircular deviation. The fore-and-aft and transverse

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axes of the ellipse give the amount of the fore-and-aft transverse inductive forces which give rise to the quadrantal deviation. An ellipse so drawn, therefore, gives to the eye, at a glance, the whole magnetic character of the ship as regards deviation on an even keel.

If the mean directive force of the needle is not altered, the ellipse becomes a circle, the coordinates of the centre of which are $\mathfrak{B}$ and $\mathfrak{C}$, and the radius $\mathfrak{D}$, on the scale in which the mean force to north represents unity. If we have no observations of horizontal force, the circle is all we can draw; it gives all the information to be derived from the ellipse, except the diminution of the directive force. For the complete representation of the deviation and force, it is convenient to have both the circle and the ellipse drawn.

In the diagrams the direction and force of the earth's magnetism as the ship is on different azimuths are represented by the radius of a circle, of which the compass is centre, and which is divided in the reverse order of the compass-card. A line drawn from a point in the circle to the corresponding point in the ellipse or small circle represents, on the common principle of the parallelogram of forces, the direction and amount of the force on the needle[*]. A modification of this diagram is described at p. 96 of the 'Manual' under the name of "dygogram" (dynamo-gonio-gram), applied to it from its showing the *force* as well as the *angle* of deviation of the needle.

The principle of its construction is the following. If we draw a vertical line representing the magnetic meridian, and from a given point in it draw lines representing in length and direction the directive force and direction of the needle for each azimuth of the ship's head, the extremities of such lines will trace out an epicycloid which is very easily constructed by points when the coefficients $\mathfrak{A}$, $\mathfrak{B}$, $\mathfrak{C}$, $\mathfrak{D}$, $\mathfrak{E}$ are determined. The method is applied in plate 2 to the deviations of the standard compass of the 'Warrior,' and has been applied by us to many other ships, and has been found a most efficient aid in discussing the observed deviations[†].

We now come to what we consider the proper subject of this Report, viz., the practical results as to the deviations of the compass which have been deduced from actual observation on board ship; and the works to which we shall principally confine our attention are the following:—

"Account of Experiments on Iron-built Ships, instituted for the purpose of

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[*] A practical application of the diagram to the correction of the compass was suggested by its being accidentally held to the light and looked at from behind. When this is done, it will be seen that the large circle is divided in the same way as the compass-card. If, then, the radius of the large circle represent the direction of the disturbed compass-needle, the line joining the corresponding points in the large circle and on the ellipse or small circle will represent the direction of the magnetic meridian.

By therefore drawing on an ordinary compass-card a circle of which the coordinates of the centre are $-\mathfrak{B}$ and $+\mathfrak{C}$, and the additional coordinates of the north point $-\mathfrak{D}$, and dividing the small circle in the reverse order, we get the following rule for the correction of the compass:—

"Take the given course on the card, and also on the small circle, and suppose a straight line drawn through these. Then keep the ship's head in the direction of the line, disregarding, of course, the lubber-line."

[†] If X be the force to north in terms of the mean force to north, Y the force to east, then X and Y representing rectangular coordinates,

$$X=1+\mathfrak{B}\cos\zeta-\mathfrak{C}\sin\zeta+\mathfrak{D}\cos 2\zeta-\mathfrak{E}\sin 2\zeta,$$
$$Y=\mathfrak{A}+\mathfrak{B}\sin\zeta+\mathfrak{C}\cos\zeta+\mathfrak{D}\sin 2\zeta+\mathfrak{E}\cos 2\zeta,$$

which is the equation to an epicycloid traced out by a point $\sqrt{\mathfrak{D}^2+\mathfrak{E}^2}$ from the centre of a circle whose radius is $\sqrt{\mathfrak{B}^2+\mathfrak{C}^2}$, and which rolls on a circle of equal size, and the coordinates of the centre of which are $X=1$, $Y=\mathfrak{A}$.

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discovering a Correction for the Deviation of the Compass produced by the Iron of the Ship, by G. B. Airy, Esq., Astronomer Royal" (Phil. Trans. 1839, p. 167).

"Discussion of the Observed Deviations of the Compass in several Ships, wood-built and iron-built, by G. B. Airy, Esq." (Phil. Trans. 1856, p. 53).

"Practical Illustrations of the Necessity for Ascertaining the Deviations of the Compass, &c., by Capt. Edward J. Johnson, R.N., F.R.S., Superintendent of the Compass Department of the Royal Navy." 1st edition, 1848; 2nd edition, 1852.

"Magnetical Investigations by the Rev. W. Scoresby, D.D." 2 vols. 1844–1852.

"Journal of a Voyage to Australia and round the World, for Magnetical Research, by the Rev. W. Scoresby, D.D." Lond. 1859.

"First and Second Reports of the Liverpool Compass Committee to the Board of Trade, 1857."

"Third do., 1861."

"Reduction and Discussion of the Deviation of the Compass observed on board of all the Iron-built Ships, and a Selection of the Wood-built Steam-ships in Her Majesty's Navy, and the Iron Steam-ship 'Great Eastern,' by F. J. Evans, Master R.N., Superintendent of the Compass Department of H. M. Navy" (Phil. Trans. 1860, p. 337).

The first and most important general result which is derived from all the observations recorded in these works, and from many more which have not been published, is, that the observed deviations are represented by the formulæ derived from Poisson's theory with a correctness which is within the limits of error of observation.

In saying this, we are in some degree differing from a conclusion which the Reports of the Liverpool Compass Committee draw from observed deviations, viz. that there is a difference in the amount of the quadrantal deviation in different quadrants, depending either on some quality of the iron as regards its capacity for induction in different directions, or on the greater or less time occupied in moving the ship's head over one or other of the quadrants. That some difference may, under certain circumstances, be caused by the latter cause we do not dispute, but we are not satisfied that it is appreciable in the ordinary process of swinging. On the contrary, we believe that, within very small limits of error, Poisson's theory may be considered as exact for the ordinary process of swinging a ship. As regards more lengthened periods, particularly when the ship has been exposed to mechanical violence, the hypothesis no doubt ceases to be exact; but even then the most convenient mode of treating the subject is analogous to that which is familiar in physical astronomy and other mixed sciences, viz. to consider the theory as exact, but the coefficients derived from that theory as being themselves subject to changes to be derived from observations, and reduced or not, as the case may be, to law.

Mr. Airy, in the first paper to which we have referred, describes very careful observations made by him on board of two iron ships, the 'Rainbow' iron-built steamer, and the 'Ironsides' iron-built sailing-ship. In the first, observations were made at four stations: station 1, near the binnacle, 13 feet 2 in. from the stern; station 2, at a part in which a standard compass would probably be placed, being 31 feet 9 in. from the stern; station 3, 48 feet 3 in. from the stern; station 4, 47 feet from the knight-heads, or 151½ feet from the stern. Each compass was raised 4 feet from the deck. In the 'Ironsides' the compass was placed in the position of the binnacle compass.

From Mr. Airy's observations we derive the following values for the coefficients:—

	A.	B.	C.	D.	E.	λ.
	° ′	° ′	° ′	° ′	° ′	
'Rainbow,' station 1	+ 0 40	− 50 36	− 11 4	+ 1 23	+ 0 38	·984
" " 2	+ 0 35	− 18 45	− 12 57	+ 2 30	+ 0 2	·973
" " 3	+ 0 42	− 15 46	− 10 39	+ 3 07	− 0 2	1·003
" " 4	+ 0 5	− 8 5	− 9 33	+ 3 26	+ 0 2	·999
'Ironsides'	+ 0 9	− 24 16	+ 20 59	+ 2 06	+ 0 16	·908

The most remarkable features in the deviations of these ships are the very small amount of the quadrantal deviation, and also in the 'Rainbow' the small diminution of the horizontal force.

These features led Mr. Airy to the conclusion that the amount of induced magnetism was small, and that nearly the whole of the semicircular deviation was caused by permanent magnetism. That this was the case as regards the coefficient C there can be no doubt; but as regards the coefficient B the case is different, as any part of it may have arisen from the induction in vertical masses of iron before or abaft the compass.

These results, and the conclusions which Mr. Airy drew as to the amount of permanent magnetism, were the foundation of his well-known method of correcting the deviations by means of magnets and soft iron, which has been so extensively practised in the mercantile marine.

Another remark may be made on the results. One of the most important conclusions which have been drawn from the numerous observations which have been made on the deviation of iron-built vessels is, that, in a well-selected place for the standard compass, the semicircular deviation depends on the position of the ship in building, the magnetism which would be assumed if the iron were soft being then, by the process of hammering, fixed in the vessel, and a character then impressed which the ship never afterwards loses,—the general result being that *the north point of the compass is attracted to that part of the ship which was south in building*, so that +B indicates a ship built head south, −B a ship built head north of the (magnetic) east and west line, +C a ship built head east, and −C a ship built head west of the magnetic meridian. With our present knowledge, we should have little hesitation in drawing the conclusion from Mr. Airy's observations, that the 'Rainbow' was built with her head not far from N.W., and the 'Ironsides' with her head not far from N.E. At that time, however, the connexion between the direction of building and the semicircular deviation was unsuspected*, and the direction in which those ships

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* To this there is one exception, which deserves to be recorded. In the year 1835, Captain Johnson made elaborate experiments on the magnetism of the iron steam-vessel 'Garry Owen,' the results of which are contained in a paper in the Phil. Trans. for 1836, p. 267. Captain Johnson ascertained, from observations made on a needle on shore, that the 'Garry Owen' acted as a permanent magnet, her head repelling, and her stern attracting, the north end of the needle; and he says, p. 285:—"As, in the construction of iron vessels, hammering the numerous rivets might elicit magnetic influences, it would be well to note, by compass, the direction of their heads and sterns when building, with a view of ascertaining whether (in combination with the former circumstances) any distinct magnetic properties indicated by those parts are due to the line of direction of the vessel with respect to the magnetic meridian."

"The head of the 'Garry Owen,' when building, was W.N.W."

It may seem singular that Captain Johnson did not observe how nearly this direction were built was probably unknown to Mr. Airy. He suggested that the particular character of the semicircular deviation in these vessels might be due to the direction of rolling of the plates of which the ship was composed. Subsequent experiments, made by the same eminent philosopher, on iron rolled in different directions, lately communicated to the Royal Society, but not yet published, show, as we understand, that the effect of direction in rolling, though appreciable in each separate plate, is not great, and probably has little, if any, appreciable effect in a ship. In concluding our observations on the paper, we must not omit to say that one of the most valuable parts of Mr. Airy's paper, viz. the mechanical correction of the deviation, does not, as we consider, come within the scope of this Report, and that, in passing it over, we must not be considered as underrating its importance.

Mr. Airy's second paper has not that value which is given to the first by careful observations made by himself on selected ships. It contains a discussion equivalent to the determination of $\mathfrak{B}$, $\mathfrak{C}$, and $\mathfrak{D}$ of the magnetism of various wood-built and iron-built ships from observations made in various latitudes, and an endeavour to deduce from such observations the two parts of which $\mathfrak{B}$ is composed; but Mr. Airy had the disadvantage which is still met with by those who attempt the discussion, viz. the want of sufficient determinations of the deviations of *the same* iron vessel in *different* magnetic latitudes, and he was consequently unable to obtain any very precise evidence of the amount of the subpermanent magnetism in iron ships, or its change on a change of latitude.

The work of Captain Johnson, to which we have referred, is a great storehouse of the results of observations of deviation made on board ships of war. There are, however, several reasons why it does not require very detailed mention here. The deviations are chiefly those of wood-built ships. They are, therefore, generally small and regular. They are not compared with theory, and do not in all cases furnish sufficient data for the comparison. Such comparison as can be made will, as regards iron-built vessels, be found in Mr. Evans's paper in the Phil. Trans. of 1860, referred to above.

It is to Dr. Scoresby that we are indebted for the observation that the semicircular deviation of iron ships is chiefly due to their position when building.

In considering this subject, there are one or two points which must be borne in mind. Supposing, as we may no doubt do, that the iron is, as regards position and quality, symmetrically placed on each side of the midship line, we may consider separately the permanent or subpermanent magnetism caused by fixing, first, the magnetism induced by the horizontal force, and secondly, that induced by the vertical force. As regards $\mathfrak{C}$, the same reasoning which shows that it cannot arise from transient induced magnetism also shows that it cannot be caused by the fixing any vertically induced magnetism, but must arise either from independent permanent magnetism in the iron, or from fixing the horizontally induced magnetism.

On the other hand, as regards $\mathfrak{B}$ the case is different. It may be caused not only by the subpermanent magnetism originally induced by the horizontal force, and fixed in building, but by transient vertically induced magnetism, and also by the subpermanent magnetism arising from fixing, in the process of building, the transient vertically induced magnetism. Between

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approximated to that of the line of no deviation in the 'Garry Owen,' which was about N.W. by W. ½ W., and that in his subsequent works he did not revert to the subject; and that the hint here given was not pursued by subsequent investigators.

these there is the great difference that the force which gives rise to 𝕮 and to the first part of 𝕭 ceases to operate, or at least ceases to operate in the same direction, the moment the ship has been launched, and has her head directed to different points of the compass, while the force causing the other part of 𝕭 continues to act in its original direction as long as the ship remains in and near its original geographical position.

𝕮, whatever its magnitude, may therefore be expected to diminish rapidly after launching, and until the originally impressed magnetism reaches (as it appears ultimately, and in fact after no long period, to do) the limit beyond which sensible change does not proceed, and on a change of latitude it will vary inversely as the horizontal force. 𝕭, on the other hand, although it may change considerably after launching, if the ship has been built north or south, will, if the ship has been built east and west, remain unchanged. On the other hand, on a change of magnetic latitude, while the effect of the subpermanent magnetism induced by the horizontal force will vary inversely as the horizontal force, that part which has been caused by the original vertical magnetism may change more rapidly from the change in the inducing cause, and the remaining part, or the transient vertically induced magnetism, will in its effect vary as the tangent of the dip.

The combination of these several causes renders the discovery of the true source of the 𝕭 a matter of great difficulty, even when observations have been made in several different latitudes.

That the distribution of the permanent magnetism of iron ships is principally owing to their position in building appears to have been first strongly insisted on by Dr. Scoresby in the 4th Part of his magnetical investigations published in 1852. The great importance of the service thus rendered by Dr. Scoresby cannot be over-estimated. Dr. Scoresby also endeavoured to investigate the changes which the subpermanent magnetism of a ship undergoes on a change of magnetic latitude. He did so, however, with very insufficient materials, and it appears to us (as one of us has endeavoured to point out with greater detail in the introduction to the 'Journal of a Voyage of Magnetic Research'), without having sufficient regard to the amount of transient vertically induced magnetism which acts or may act as a cause of semicircular deviation.

At the meeting of the British Association at Liverpool in 1854, Dr. Scoresby brought the subject of the change of a ship's magnetism prominently before the Association, in a paper on the loss of the ship 'Tayleur' and the changes of the compasses of iron ships. The discussion so occasioned gave rise to the formation of the Liverpool Compass Committee, whose valuable Reports are one of the special subjects on which we are commissioned to report, and also to Dr. Scoresby's voyage in the 'Royal Charter' for the purpose of observing the changes which take place in the magnetism of an iron ship on a change of magnetic latitude. To these we now address ourselves.

The Liverpool Compass Committee have had the assistance throughout of a most able Secretary, Mr. W. W. Rundell, who has brought to the subject an amount of practical and scientific knowledge, combined with industry and zeal, which have given to the three Reports which have been published the highest possible value.

The first Report bears date the 5th of February, 1856, shortly before Dr. Scoresby sailed in the 'Royal Charter.' The second Report bears date February, 1857, and embodies the principal results of the observations in the 'Royal Charter.' The third Report bears date the 13th of February, 1861.

The first Report was merely preliminary, and stated the steps which the Committee were taking to obtain information. One of the few points on which the Committee had made observations, the details of which they give, was the direction of the neutral lines, or of those lines in the iron structure of the ship which separate the parts in which the iron attracts the north end of the compass-needle from those in which it attracts the south end. These observations, we may observe, though to a certain extent useful as enabling us to see generally the nature of the action of the body of the ship on the compass, do not give any very definite results, from the transient induced magnetism being even more mixed up with the permanent or subpermanent magnetism than in the case of ships "swung."

The Committee, in the first Report, draw the following inference from these observations, viz. that "the diverse direction of the magnetic lines appears to countenance Dr. Scoresby's supposition that they depend on the position of the ship when building."

The second Report contains the results of much more extended observations and matured views. On the point of most marked importance—the connexion of the magnetism of an iron ship with her position when building—the Committee had now arrived at a definite opinion. They say:—"The records of the Committee no longer allow a doubt as to the connexion which exists between the direction of a ship's original magnetism and her position when upon the building-slip. In all the ships which have been examined, the north end of the compass-needle invariably deviated towards that part of the ship which was furthest from the north when she was building, *if the compass was placed in a central position and free from the influence of individual masses of iron.*" *

The attention of the Committee was also directed to the changes which the deviations undergo shortly after an iron ship has been launched, and they came to the conclusion that the subpermanent magnetism undergoes considerable changes at and immediately after launching, and during the first voyage; but that after this early reduction of a ship's magnetism has taken place, the remaining portion appears to be comparatively permanent. This, however, is subject to the qualification mentioned in the Report, and which may be stated as follows:—that when a ship has been for a considerable time in one position or on one course, the induced magnetic state acquires a certain degree of permanence which modifies the previous subpermanent magnetism. The general effect of this, it will be easily seen, is upon a change of course to cause the vessel to deviate from her course, by dead reckoning, *in the direction of her previous course.*

In this Report attention is called to the very important subject of the variation of the directive force in iron ships on different points of the compass. With reference to this, it may be observed, that we think it is a result of the observations generally, that the degree of correctness of observations of *force* is much inferior to that of observations of *deviation*. The observations of deviation give, by theory, the *proportions* of the directive forces on the different courses. Each observation of force, therefore, when compared with the proportionate force derived from the deviations, gives a value of the factor (λ) by which the forces derived from the deviation ought to be multiplied.

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* We have distinguished by italics the last part of this sentence in order to draw attention to one circumstance which continually forces itself into notice in the perusal of the Reports, viz. the very little attention which is paid in the mercantile marine to the selection of a place for the compass. In these ships the compass is constantly placed so near iron sternposts, spindles of capstans, bulkheads, roundhouses, spindles of wheel, &c., that the effect produced on the compass is not only extravagantly large, and the rapidity of variation of the force in the field very great, but the effect produced is in truth not so much that caused by the ship considered as a whole, as that caused by the particular masses of iron in the vicinity of the compass.

The second Report of the Liverpool Compass Committee also mentions the interesting fact, which has been completely verified in the ships of the Royal Navy, that the quadrantal deviation of all ships is, with very rare and special exceptions, positive, or such as to cause a deviation of the north end of the compass *to* the north *end* of the ship and *from* the north *side* of the ship. Such a deviation might be caused by an *attraction* to the north *end* or a *repulsion* from the north *side*. We may distinguish between the two causes by observing that the former would increase, and the latter diminish, the mean directive force of the needle. Observations of the directive force, therefore, show from which cause this deviation arises, and indicate that in general in iron-built ships the quadrantal deviation is principally caused by the *repulsion* of the north *side* of the ship, the north *end* of some ships attracting the north point of the needle, of others repelling it, but in almost all such ships with a force inferior to that of the repulsion of the north *side*. In wood-built ships the case is different: there is no transverse horizontal iron to cause repulsion from the sides; and the positive quadrantal deviation is caused by the attraction of the masses of iron before and abaft the compass. The exceptions are generally in the case of wooden screw-streamers, when the screw-shaft, passing through the place of the compass, causes a repulsion from the north end, or in the case of elevated compasses, in which the original +D has depended on an excess of repulsion of the sides over the repulsion of the ends. As the compass is elevated, the direction of the former force, becoming more oblique, loses its effect much more rapidly than the latter, and the D consequently changes its sign.

The Committee also observed on the heeling error, and on the general tendency being to draw the north end to the weather side, but stated that the evidence which they had obtained did not enable them to draw any definite conclusions on this subject.

The third Report embodies the results of very extended and varied observations, leading to very definite conclusions, which may nearly to the full extent be accepted as being now established.

As we have already observed, the present state of the mathematical theory is such, and the mathematical results coincide so exactly with observations, that the details of observation lose much of their interest, and the results involved in the coefficients extracted by rule from the observations are sufficient for all practical as well as theoretical purposes.

The Report commences with a summary of the points which the Committee consider as established; they are—

1. That the magnetism of iron ships is distributed according to precise and well-determined laws.
2. That a definite magnetic character is impressed on every iron ship while on the building-slip, which is never afterwards entirely lost.
3. That a considerable reduction takes place in the magnetism of an iron ship on first changing her position after launching, but afterwards that any permanent change in its direction or amount is a slow and gradual process.
4. That the original magnetism of an iron ship is constantly subject to small fluctuations from change of position arising from new magnetic inductions.

5. That the compass-errors occasioned by the more permanent part of a ship's magnetism may be successfully compensated, and that this compensation equalizes the directive power of the compass-needle on the several courses on which a ship may be placed.

The first two points we have already adverted to, and we fully agree with the Committee in considering that they may now be accepted as well established.

The third point is one of the most important of the results to which the making, registering, and discussing the observations of deviation in iron ships is at present leading us.

It is clear that when an iron ship is first launched, her magnetic character depends almost entirely on her position in building, but that this magnetic state is extremely unstable; that very great changes take place within a few days, or even hours, after launching; but that, after no long time (the length of time depending no doubt, to a great extent, on the service in which the vessel has been employed), what may be called the temporary magnetism gets "shaken out" of her, and the magnetism of the ship acquires an extremely stable character. This is a matter on which exact and varied observations are much wanted; but we think it may be taken at present as the most probable result, that after about twelve months there is very little change in the magnetism of a ship which has made some voyages in the interval. In some ships the stability is most striking. It must, however, be remembered that it does not follow from this that the whole of the magnetism which remains, and which affects the compass, is the permanent magnetism of hard iron. There is in all iron ships, as shown by the amount of the quadrantal deviation, a large quantity of soft iron, and consequently a large quantity of magnetism developed instantaneously (or nearly so) by induction; and the magnetism developed in the soft iron by vertical induction is not, in any given geographical position, distinguishable from the permanent magnetism of hard iron. The test of the kind of permanence which is acquired by the magnetism of an iron ship after the lapse of the period we had referred to is, that her table of deviation shall always be the same when swung at the same geographical position. If, in addition to this, her semicircular deviation in different parts of the globe is inversely proportional to the horizontal force of magnetism at the place, we infer that the vertically induced magnetism is so distributed as to produce a compensation of effects, and that the only cause which operates is the permanent magnetism of the hard iron. In some ships this appears to be the case. In H. M. S. 'Trident,' which has been particularly discussed by Mr. Airy, the magnetism is not only extremely stable, but nearly the whole of the semicircular deviation appears, from observations made in various latitudes, to be due to hard iron. The same is the case with H. M. S. 'Adventure' and with many other iron ships.

The practical conclusion which, it appears to us, may be drawn from these facts, is the importance in all iron ships of having their magnetic history carefully recorded, and the observations discussed. We need hardly say that, to give any value to such a record, observations should be made with the compass in a fixed position in the ship, and not corrected in any way by magnets or soft iron.

On the fourth point we have, in fact, already expressed our opinion. We are not satisfied that the effects here referred to are in general of appreciable amount in so short a space of time as that occupied by the process of swinging a ship. There seems, however, no doubt that the cause operates sensibly in many cases when a ship has been long sailing in one direction; and this remark might be taken as a qualification of what we have remarked as to the permanence of the magnetism of a ship.

On the fifth point we quite agree with the Liverpool Compass Committee, subject, however, to the qualification that this correction cannot be depended on in the case of a newly-built ship, and that when the correction is applied to compasses having large deviations, and placed near large vertical masses of iron, as a stern-post, there must always be great uncertainty as to the correction on a change of magnetic latitude. It is also right that we should not pass over this remark without protesting against the application of such correction to the standard compass (properly placed) of a ship which may be called on to make a voyage during which there is any great change in the dip or horizontal force.

The Committee notice as the principal points left for further discussion and inquiry, the effect of heeling on the compasses of iron ships, and the changes which occur on a change of magnetic latitude; and to these the Report is chiefly directed.

On the effect of heeling a considerable body of evidence is collected, but with the disadvantage that at that time the mathematical theory of the heeling error, and the formulæ which express it, had not been fully investigated, and that consequently the comparison of theory with observation could not be precisely made; nor do the observations in all cases furnish sufficient data for the comparison.

We think, however, that it may be said, with confidence, that the results of observations agree with theory as to the connexion between the amount and direction of the heeling error and the coefficients of quadrantal deviation and of horizontal and vertical force; and that we may therefore feel assured that the heeling error may be predicted with sufficient accuracy from observations made on an even keel.

The most important practical results as to the amount of the heeling error, are the very great amount to which it reaches in certain ships, and in certain positions in the ship. This heeling error is conveniently measured by the fraction of a degree or the number of degrees of error produced by every degree of heel when the ship's head is North or South. Estimating it in this way, it will be seen that the error may have serious effects if it exceed ·5 or ·6, when an inclination of 10° may produce half a point of error.

Among the examples given we have—

Iron S. S. *City of Baltimore* (built head North).	Coefficients of heeling error.
Compass placed above the aft end of iron round-house ..	+6·70
Port steering-compass compensated	− ·30
Starboard steering-compass compensated	− ·50
Standard compass	+2·20
Azimuth compass................................	+2·
Dipping-needle compass	+2·
Fore compass compensated	+ ·80
Compass over fore hatch	+ ·85
Aphrodite (built head East).	
Compass under companion	+2·
Compass near companion..........................	+2·85
Admiralty standard compass	+1·20
Dipping-needle compass	+1·15

	Coefficients of heeling error.
Simla (built head West).	
Steering-compass	+2·06
Compass over companion	+1·65
Dipping-needle compass	+ ·80
Standard compass	+ ·73
Forward compass	+ ·70
Slieve Donard (built head S.E. to E.).	
Aftermost steering-compass compensated	+ ·40
Second steering-compass compensated	+ ·12
Skylight-compass compensated	+ ·33
Mast-compass	+ ·23
Port skylight compass	+ ·26

In other compasses of the 'Slieve Donard' the heeling error was almost imperceptible. In the case of the 'City of Baltimore,' the large heeling error is evidently due to the vertical force downwards near the stern, arising from the ship having been built head north. In the 'Slieve Donard,' the small heeling error is evidently due to the ship having been built with her head to the southward.

Before leaving the subject of the third Report, we must beg leave to mention one point which has made the duty of reviewing the Report more difficult than it would otherwise have been, and which we fear will detract from its general utility, viz. that the mathematical formulæ made use of in reducing the observations are nowhere given, and that we have been unable, in some cases, to verify or use them. We hope that the Admiralty Manual may be of some use to future investigators, as providing a uniform notation and mode of reduction, which will make the results derived by one investigator intelligible to all.

In concluding this notice, we think we may say that the principal desiderata at present are—

1. That in the construction of iron vessels, regard should be had to the providing a proper place for the compass. It is not difficult for any one who has studied the question to point out arrangements which would greatly mitigate the injurious effects of the iron of the ship; the difficulty is to reconcile them with the requirements of construction and of working the vessel.

2. That for throwing light on the points which are still obscure, what is chiefly required is, that the complete magnetic history of some iron vessels in various latitudes should be known. This, we think, might easily be accomplished by observations of deviations and horizontal and vertical force made at various fixed positions in an iron vessel in an extended voyage in both hemispheres. We need hardly add, that this should be a vessel of war of moderate size, and in which the magnetical observations would be made an object of importance.

Report on Tidal Observations on the Humber. Presented by JAMES OLDHAM, *C.E.;* JOHN SCOTT RUSSELL, *C.E., F.R.S.;* J. F. BATEMAN, *C.E., F.R.S.; and* THOMAS THOMPSON.

AT the Meeting of the British Association held at Manchester last year a paper was read in Section G, on the Port of Hull, in which occurred the following remark, referring to the tides of the Humber: "I would notice here a singular tidal phenomenon which exists at the Port of Hull; I refer to the fact, that whenever the tide reaches the 16-feet mark" (over the dock-sill), "it is then three hours to high water, whether they be spring tides or neap tides. I am not aware that the same thing occurs at any other port; but such is the fact at Hull, that three hours after the tide has attained to the 16-feet mark, there is no more rise."

These remarks gave rise to an animated discussion on the alleged phenomenon, and resulted in the appointment of the following members of the Association as a Committee to conduct a series of tidal observations on the Humber, and report on the same to the next Meeting to be holden at Cambridge, viz. Mr. James Oldham, C.E., Mr. John Scott Russell, C.E., F.R.S., Mr. J. F. Bateman, C.E., F.R.S., and Mr. Thomas Thompson, with £25 at their disposal.

In commencing the arrangements for carrying out the wishes of the Association, application was made to the directors of the Manchester, Sheffield, and Lincolnshire Railway Company for a month's observations to be taken at their self-acting tide-gauge at the Great Grimsby Docks, but it was not convenient to the directors to grant the request; they, however, permitted a gauge-pole to be fixed at their landing-pier at New Holland, on the Lincolnshire coast of the Humber, a little above Hull, and gave every facility in the progress of the operation of observing the tides.

The Hull Dock Company, through their secretary, Mr. W. H. Huffam, have complied with a request to have a month's observations from their self-acting gauge of the Victoria Docks; and the resident engineer of the company, Mr. R. A. Marrillier, has furnished the month's valuable tidal observations.

Mr. Thomas Wilson, of Leeds, an active member of the British Association, kindly offered a month's observations from the self-acting tide-gauge of the docks of the Air and Calder Works, at the Port of Goole, on the river Ouse, which have also been furnished by Mr. W. H. Bartholomew, the resident engineer.

Those on the Humber were commenced at or about 11 A.M., July 9th, and terminated at 3 P.M., August 6th; but those at Goole, which were begun at 11 A.M. on the 9th July, were continued until twelve o'clock at noon on the 10th of August.

The gauge at New Holland is so fixed as to correspond with, and is on the same level as, the Victoria Dock gauge at Hull, *i. e.* the zeros are made to coincide.

The observations were taken every five minutes at New Holland, but every fifteen minutes at the Hull Dock gauge; the observations at Goole were taken at intervals of five minutes.

As a result of these tidal investigations it was seen, by the series of observations at both the stations on the Humber, how accurately the statement is borne out as to rise of tides for three hours after attaining the 16-feet mark, and also that the time which the tide is falling from the period of high water to the same level again of 16 feet is also found to average about three hours.

The observations are also important and valuable, as showing the general rate of the rising and falling of the tides at the various periods and places reported on.

Although little or no light may have been thrown on the phenomenon in question, yet the various tidal observations obtained on the Humber and the river Ouse will no doubt prove valuable records on the question of tides.

From the various observations the following are the results:—The observations made on the Humber comprised 55 tides: the greatest variation at spring tides was 22 feet 3 inches flow; and the least variation at neap tides a rise only of 10 feet 7 inches. The lowest level of low water at spring tides was 3 feet 8 inches, and the highest rise 27 feet 11 inches; the highest at low water of neap tides 11 feet 2 inches. The mean rise of the 55 tides above low water was found to be 16·95 feet. The average time of rising tide is about 5½ hours, and the falling tide about 6¾ hours.

At the season of the year when the observations were taken it is generally calm, and there is no undue influence exerted on the rise and fall of the tides on the Humber; but at the time of the equinox, and in stormy winter seasons, particularly during north-westerly gales, there is a much greater rise and fall during spring tides than would otherwise occur.

The observations made at Goole (which port is about 30 miles above Hull) show on the 63 tides a mean rise of 11·67 feet,—the greatest rise above low water being 15 feet 4 inches, and the least rise from low-water line 7 feet 7 inches.

The tides at Goole average about 3 hours in rising, and a little over 9 hours in falling.

The mean rate of the tidal wave on the Humber is from 2½ to 3 miles at neap tides, and 4 to 5 miles per hour at spring tides.

On Rifled Guns and Projectiles adapted for Attacking Armour-plate Defences. By T. Aston, *M.A., Barrister at Law.*

[A communication ordered to be printed among the Reports.]

As it is now an admitted fact that naval warfare will be carried on by iron-clad navies, it has become an imperative necessity that the navy of England shall henceforth be armed with artillery adapted for attacking the new armour-plate defences which all nations are hastening to adopt. The superiority which defence so suddenly acquired over attack, by simply putting on a coat of armour, threatened to upset not only the theoretical but the practical tactics of modern warfare. The necessity of improving the means of attack so as to restore, as far as possible, the disturbed equilibrium was obvious to every one; and the contest which has been carried on in this country for the last two or three years between the attack of improved artillery and the defence of improved armour-plates has been watched by all of us with the greatest interest. From a scientific point of view, with which we are on this occasion more immediately concerned, the subject was one which engaged the attention of some of the keenest and most experienced intellects of the country,—these, on the one hand, giving practical aid on the side of defence, those, on the other, devoting their best energies to restore attack to what must be considered its normal position of superiority. For a long time—for too long a time—the defence-people had much the best of it. Under the energetic superintendence of the Plate Committee (who in this matter de republicâ bene meriti sunt), armour-plate targets were erected by our able engineers which at fighting-ranges laughed to scorn the utmost efforts of the artillery attack brought against them. Some of the targets combined the resistance of iron with wood; others, constructed with far-seeing ingenuity, depended upon iron alone. The Ordnance Select Committee were challenged to bring forward the best gun their artillery science, aided by all the resources of the Royal arsenals and the public purse, was able to provide. The science brought to bear by the Ordnance Select Committee, after exhausting itself in repeated efforts to cover its repeated defeats (efforts that were fruitless for reasons that will be explained), was at length compelled to confess itself vanquished. But Ordnance had other resources which it hoped to have dispensed with, and upon which in its disappointment it was glad to fall back: it said to the Committee of Defence, "If you will obligingly set up your armour-targets within a shortened range (say, for instance, a Robin Hood bowshot of 200 yards), you shall see what the brute force of the old smooth-bore will do. True it is that cast iron will be brought to attack wrought iron—that a rounded missile will have to punch its way through a flat and possibly at times inclined armour-plate—science, which proved but a broken reed in our hands, must be abandoned; but with a gun big enough, a shot heavy enough, a charge of powder large enough, and a range short enough, the smooth-bore shall smash your target." Of course it would; and so would a battering-ram like those Titus used to break the gates of Jerusalem. If therefore the old smooth-bore had failed the Ordnance Committee, like the service rifled gun, they might have fallen back on the older battering-ram.

Looking at it from a scientific point of view, this retrogression was very humiliating, and it caused the country serious anxiety to hear Her Majesty's Ministers state in Parliament, as they did in the last session, on the authority, of course, of their official scientific advisers, that the Navy of England, after all the vast expenditure that had been lavished upon it, was at last obliged to be armed with the old smooth-bores to meet the iron-clad navies of her possible enemies. This was indeed proclaiming England's weakness to other nations who were more scientifically informed and better armed than she.

In further explanation of what was the actual condition in which this all-important question stood no later than May last, I will quote the statement of Sir William Armstrong, who, at a meeting of the United Service Institution, May 20, 1862, expressed himself in these words:—"It *certainly* may be said that shells are of no avail against iron-plated ships; but, on the other hand, I may say that neither 68-pounders nor 110-pounder guns with solid round shot are effective against such iron vessels. The fact is, what we want is a gun, in addition to our 110-pounder rifled gun, especially adapted for breaking through iron plates. That is what we are in want of now." This statement made in 1862 was very startling to all of us, who knew that long ago France armed her 'Gloires' and 'Normandies' with rifled 90-pounders said to be efficient against iron plates. Such being the state of the question a few months back, we may proceed to consider, first, the reason why the artillery hitherto employed in the service, including rifled guns and smooth-bores, has always failed to make any impression on the plated defences at ordinary fighting-range; and secondly, by what means artillery science has lately reconquered its lost ground. Sir William Armstrong put the case very plainly when he said that shells were in fact of no avail against plated ships, and that the solid shot of the 110-pounder rifled gun was not effective against such iron vessels. But late experiments at Shoeburyness, in which the 'Warrior' target was pierced and shattered at 600 yards, have proved that the case as put by Sir William Armstrong was based on his experience of shells that were not made of the proper form, nor of the proper material, and on his experience of rifled guns that were unable to propel their projectiles with the requisite velocity.

Three conditions may be laid down as necessary to enable artillery to attack successfully armour-plate defences: 1st, the projectile must be of the proper form; 2nd, of the proper material; and 3rd, be propelled from a gun able to give it the necessary velocity. The artillery of the Ordnance Select Committee failed because they utterly neglected the first two conditions, and had recourse to the brute force of the smooth-bore for the third. The expression accepted as representing the penetrating power of shot was "velocity squared, multiplied by weight;" but the form of the shot and the material were conditions altogether omitted from the expression; and the importance of the omission will be obvious at once if we take an analogous case, say that of a punching-machine employed to perforate wrought-iron plates. What would be the result if the punch itself, which is made of suitable shape and material, were removed, and a round-headed poker, of brittle cast iron or soft wrought iron, were substituted in its place? The great importance of sufficient velocity is conceded—it is a *sine-quâ-non* condition; but has there not been great misconception in supposing that the old smooth-bore gives a greater initial velocity than the rifled gun? The results obtained will show how this is. The average initial velocity of the 68-pounder is, in round numbers, 1600 feet per second with a charge of powder one-fourth the weight of the shot, the length of the shot being of course one calibre. Sir William Armstrong stated that with a charge of powder one-fourth the weight of the shot, he obtained with his rifled gun an initial velocity of 1740 feet per second: he did not state the length of his projectile. Mr. Whitworth, with a projectile one and a half calibre long, obtains an initial velocity of 1900 feet per second; and with a projectile one calibre long, like that of the smooth-bore, an initial velocity of 2200 feet per second, being greater than that of the smooth-bore in the proportion of 22 to 16. The reason why, under nearly similar conditions as to charge and length of projectile, the rifled gun had an initial velocity so greatly superior to that of the smooth must be ascribed to the action of the first condition I ventured to lay down as necessary. The rifled projectile, as compared with the spherical, has a form which is better adapted for flight, and fits more accurately the bore of the gun, so that the gases of explosion exert a greater pressure upon it while propelling it through the barrel. In practice the initial velocity of the rifled projectile is lower than that of the smooth-bore, because with the rifled gun the charge of powder used is much less, while the projectile is much longer and heavier, and has a greater *vis inertiæ* to be overcome at starting than that of the smooth-bore. If very large charges be used with the rifled guns, and long projectiles, with the view of obtaining increased velocity, the strain becomes too great for the guns to bear; but if rifled guns are fired with charges so low that they are not made to perform half the work they ought to do, then, though the defects of weak construction may not be made patent by the gun being destroyed, they are very plainly manifested by the weak results of their projectiles fired against armour-plates. It is proved by well-known results that the constructors of the 110-pounder rifled gun, now adopted in the service, do not dare to make the gun perform its full work; but, on the contrary, they find themselves forced gradually to reduce their charges, until they are well beaten by the old smooth-bore they undertook to supersede. The only conclusion that can be drawn from this fact is, that the gun is weak in construction, and the projectile used with it is defective in principle.

The power of the smooth-bore, with its large windage, to fire large charges, and thereby obtain great velocities, has procured it many advocates; but Mr. Whitworth's experiments have shown that if length of projectile be given up, which may be looked upon as the price to be paid for increased velocity, he can get an initial velocity much greater than that of the smooth-bore. But is the result worth the price paid? Not if a more efficient compromise can be obtained. I use the word "compromise" advisedly, because I think that every one who has had experience in artillery practice will agree with me that the best results are only to be obtained by means of the best compromise. You cannot have long projectiles and very high velocities without burning too much powder and taking too much out of your gun, or else making it an unwieldy monster.

The problem we have placed before us now is, How can artillery be best adapted for attacking armour-defences? The advocates of the smooth-bore are satisfied with one condition—high velocity. Mr. Whitworth objects, and says, "If velocity were all that is needed, I can get more than you do in the proportion of 22 to 16; but to sacrifice all to velocity is a bad compromise to effect a solution of the penetration-problem. You set down velocity as *greatest possible*, form of projectile *of no account*, material *of no account*, and after all can do nothing at an ordinary fighting-range while you wrongly take it as proved that '*shells are of no avail*' against iron-plated ships. It would be a far better compromise to be satisfied with a lower velocity, getting however all you can at a fair price, and combining therewith conditions *one* and *two*—proper form and proper material for the projectile." Let us now compare the actual results obtained in the way of penetration by the Armstrong 110-pounder (the proposed naval gun), the old 68-pounder smooth-bore, and the two naval Whitworth guns lately fired at Shoeburyness.

Gun.	Range.	Projectile.	Powder-charge.	Penetration into Armour-plate.
Armstrong 110-pounder, 7-inch bore	200	110 lb. solid.	14 lbs.	1½ to 2 inches.
Old 68-pounder, smooth-bore	200	68 lb. solid.	16 lbs.	2½ to 3 inches.
Whitworth 70-pounder, 5½-inch bore	200	70 lb. shot and shell.	12 lbs.	Through plate and backing.
Whitworth 120-pounder, 7-inch bore	600	130 lb. shell.	25 lbs.	Through plate and backing.

The first two results* will lead every one to the same conclusion that it is to be presumed they led the Ordnance Committee, viz. that the Armstrong rifled gun is a worse compromise than the old gun it was intended to supersede. The reason may be inferred from the facts to be, that besides neglecting conditions *one* and *two*, form and material of projectile, it is very much behind in respect of condition *three*, velocity; this is to be attributed to the weak construction of the gun, which cannot fire with safety efficient charges of powder, and to the use of the lead-coated projectiles. Taking all the results, they show themselves to be indisputably in favour of the Whitworth,—the old 68-pounder coming second, and the Armstrong last. Let us next examine how they stand in regard to velocity, as shown in the following Table, which, like the one given above, is compiled from official sources.

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* These results were subsequently much surpassed. The Whitworth 70-pounder penetrated 4½-inch plate and backing with shell at 600 yards range, and the Whitworth 120-pounder fired its shot and shell through 5-inch plate and 18 inches of teak-backing and ¾-inch iron-plate skin at 800 yards' range.

Gun.	Charge.	Velocity.
68-pounder	16 lbs.	Initial, 1600 feet per second.
Whitworth 70-pounder	12 lbs.	Initial, 1350 feet per second.
Whitworth 120-pounder	25 lbs.	Terminal at 600 yards, 1260 feet per second.
Armstrong 110-pounder	14 lbs.	Initial, 1210 feet per second.

With regard to initial velocity, therefore, the order of the guns may be taken to be, with the charges used—1st, 68-pounder; 2nd, Whitworth; 3rd, Armstrong. It is worthy of notice, however, that the velocity of the Whitworth 120-pounder after traversing 600 yards (a good fighting-range) was found actually to be 1260 feet, whereas the initial velocity of the Armstrong is only 1210 feet.

The total results in respect of penetration proving themselves to be so decidedly in favour of Whitworth, who combines with condition *three*, viz. sufficient velocity, conditions *one* and *two*, proper form and material of projectile, it follows that his must be the best compromise. The slight inferiority in initial velocity of his rifled gun, as compared with the smooth-bore, is more than compensated for by employing a projectile of proper form and material, as is shown by the penetration being through-and-through both 5-inch plate and backing in the case of the Whitworth, while it is barely half-through the armour-plate in the case of the smooth-bore, and not half-through in the case of the Armstrong gun.

The form of projectile employed by Mr. Whitworth for penetrating armour-plates is like the one now before the Section. It has a flattened front, the centre being slightly rounded; the middle part of the projectile is rifled hexagonally, like the bore of the gun; the front and rear of the projectile are made of the requisite taper to allow the air displaced in front to close in readily behind—a form which gives a great increase of velocity as compared with the form parallel throughout, as I endeavoured to explain to this Section in a paper I had the honour of reading at its meeting last year.

The material of which the projectile is composed is what is termed homogeneous metal, combining the toughness of copper with the hardness of steel: it is made hard enough to penetrate the wrought-iron plate, but not so hard as to be brittle and break up when the projectile strikes against its surface. The advantage of the flat front as compared with a pointed front is apparent, when it is considered that when the flat front strikes a plate, the whole resistance it meets with is that offered by the area of the plate covered by the flat front in a direction in line with the axis of the impinging projectile: it consequently punches out a clean hole, with a sudden impact. In the case of a pointed shot, as soon as the point begins to penetrate, the inclined sides begin to push aside the particles of the plate in a lateral direction, and an accumulating lateral resistance is offered by every part of the plate whose particles are disturbed; the passage of the shot is thereby gradually retarded, if not altogether arrested. It has been thought that the flat-fronted projectile will glance from the surface of an inclined plate like a round projectile: this is not found to be the case, as is proved by the plate now shown to the Section, which was completely penetrated by a flat-fronted projectile when inclined at an angle of 37° to the perpendicular.

The Whitworth penetration-shell, whose destructive power was shown by its penetrating and shattering the 'Warrior' target at Shoeburyness, has the same form outwardly, and is made of the same material (homogeneous metal) as the flat-fronted solid projectile which has already been described. A cavity is formed in the projectile of the size required to contain the bursting charge of ordinary powder. The rear is closed entirely by a screwed plate or cap. The uncertain complications of percussion-fuses, and also the simpler time-fuses, are wholly dispensed with. No fuse or detonating substance of any kind is used. On firing his shell through iron plates, Mr. Whitworth found that by the force of impact and friction sufficient heat was generated to fire the bursting charge without any fuse at all. In practice the action upon the powder was found to be even too rapid. To retard its action for the time necessary to enable the shell to effect a complete penetration and then to burst, Mr. Whitworth interposes between the metal of his shell and his bursting powder-charge a substance that is a non-conductor of heat: by preference he encloses the powder in a flannel case, and finds that by simply diminishing or increasing the thickness of his flannel he can burst his shell in the armour-plate or in the timber-backing, or after it has passed through both. The fragments of the shell now before the Section are those of one which was fired through this armour-plate, and which burst and shattered this backing of timber, 9 inches thick, placed behind the plate. There is one point in connexion with the Shoeburyness trials which should be specially noticed, and it is this, that all the previous experiments against the 'Warrior' target had been confined to the short range of 200 yards; at longer distances the smashing, monster smooth-bores cannot be made to hit the mark; whereas Mr. Whitworth has proved that at a good fighting-range of 600 yards he can hit his mark to a few inches, and can at that distance—and there is good reason to believe at twice that distance—send his shells through the 'Warrior's' sides. That 600 yards may be fairly called a good fighting-range will be admitted when we remember that the 'Agamemnon,' at Sebastopol, fought all the guns of Fort Constantine at a range of 500 yards; and the 'Albion' signalled, "Well done, Agamemnon!—where you lead, we will follow." With respect to the 120-pounder gun itself, it should be explained that it was made at Woolwich, under the able superintendence of Mr. Anderson, at Mr. Whitworth's own request, and according to drawings originally supplied by him. It has the same bore as the Armstrong 110-pounder, stated by Sir William not to be effective against iron-plated ships. It is a built-up gun, and its hoops are made of coiled iron, welded; but that method of manufacture was adopted by Mr. Whitworth in the first built-up gun that he made, and was well known in this country many years before rifled guns were introduced into the service.

Mr. Whitworth has himself employed by preference the homogeneous metal, which he has found to answer perfectly for small arms and field guns, as well as for the penetration-shells which have been described. Practical improvements have been made in the process of forging and annealing the metal, which now enable it to be worked in masses of any required size, whose quality may be henceforth depended upon with certainty.

Whitworth heavy guns are now being made with both interior tubes and outer of homogeneous metal of the improved manufacture, so that the guns will be constructed throughout of one uniform metal without any welding at all. Experience justifies the expectation that they will be free from the objections which it is well known are inherent in all welded guns, and be fully able to resist the severe and searching strain which is sure, sooner or later, to disable a gun built up of forged coiled tubes, if it be called upon to do its full work by discharging heavy rifled projectiles at the most efficient velocities.

Extracts, relating to the Observatory at Kew, from a Report presented to the Portuguese Government by DR. JACINTHO ANTONIO DE SOUZA, *Professor of the Faculty of Philosophy in the University of Coimbra. Communicated by* J. P. GASSIOT, *F.R.S.*

[Ordered to be printed among the Reports.]

DR. JACINTHO ANTONIO DE SOUZA has published an account of a visit in 1860 to the Scientific Establishments of Madrid, Paris, Brussels, Greenwich, and Kew, and of a second visit in 1861 to the Observatory of Kew, both visits having been made by the desire of his Government, and having for their principal object to obtain information preparatory to the establishment of a Magnetical and Meteorological Observatory at the University of Coimbra.

His first visit was to Madrid, where he states that he found nothing doing in magnetism; and that in meteorology the only instrument presenting any novelty was the ingenious and comprehensive meteorograph of Padre Secchi, intended to register atmospheric pressure, the amount of rain, and the direction and velocity of the wind. Prof. de Souza commends this instrument for the small space which it occupies, but adds that some of its indications, particularly those of temperature, appeared to him to be subject to much uncertainty. He was disposed to attribute the absence of any magnetical investigations at Madrid rather to the indifference of the Government than to any want of zeal on the part of the distinguished Director, Don Antonio Aguilar, of whose kind reception he also speaks gratefully.

He next proceeded to Paris, where he arrived on the 15th of August, "the birthday of the first Napoleon," and was dazzled with the splendour of all that met his eyes in the general aspect of that brilliant capital. He had looked forward to finding in "the Imperial Observatory directed by Le Verrier," besides a "typical Astronomical Observatory," one of the best in "magnetism and meteorology, where there would be much to see and to study;" but after obtaining access to that fine establishment, "not without difficulty and loss of precious time," he derived, as he states, "little interest and profit from the hasty view which M. Le Verrier afforded him of the Astronomical Observatory (which is indeed excellent)," whilst, in regard to the special objects of his journey, though MM. Desains and Charault courteously showed him whatever could be said to appertain to magnetism or meteorology, he states that he "came away disappointed."

At Brussels he refers gratefully to the frank and delicate kindness with which, on presenting himself at the Observatory, he was received by M. Quetelet, and expresses his admiration of what that philosopher had accomplished with means from which very few others could have educed similar results, and of the impulse imparted by him to the advancement of the "physique du globe," saying at the same time that, without this knowledge, the inspection of the magnetical and meteorological portion of the Observatory would lead a visitor to regard it as not being at the present time in a state of prosperity.

Approaching London by the Thames, and entering "the vast cupola of smoke which covers that great capital," he seems to have been powerfully impressed by the dissimilarity to what he had previously seen in France and Belgium; and by the grandeur as well as the sombre character of the spectacle presented to his view.

On arriving at Greenwich he was courteously received at the Royal Observatory, admired the general arrangements of that great establishment, and inspected minutely the magnetical and meteorological portion, with the "advantage of verbal explanations by the Rev. Robert Main, who was there at the moment, besides the written explanations kindly given to him by Mr. Airy." He thus became well acquainted with the localities, arrangements, and instruments, of which he gives a detailed description; but as he ultimately preferred ordering for his own Observatory instruments on the pattern of those employed at Kew, we may pass at once to his account of that establishment, which will be given nearly in his own words:—

"The Observatory at Kew, besides occupying itself with meteorological and magnetical phenomena, and the photographic registry of the spots of the sun, verifies meteorological and magnetical instruments, compares them with the excellent patterns which it possesses, determines their constants, and improves the methods of observation. The Director (Mr. Balfour Stewart) was absent; but Mr. Chambers, assistant observer, and Mr. Beckley, mechanical engineer of the Observatory, attended me so obligingly, and with such sincere desire to satisfy all my importunate inquiries, that I derived great profit from the visit.

"The self-registering magnetic instruments at Kew were constructed in 1857, about ten years after the registering apparatus at Greenwich was adapted to the previously existing instruments at that Observatory. Based on the same general principles, they differ in size, and in certain happy innovations introduced by Mr. Welsh and executed by Adie (a skilful artist in London). They have been in action since 1858, and give results which leave nothing to be desired.

"The locality in which the self-registering magnetic instruments are placed at Kew is in the basement-story of the building, which was formerly an astronomical observatory: the choice was determined by a condition which should never be lost sight of, viz. the greatest attainable constancy of temperature."

[Having already described the magnetographs at Greenwich, Prof. de Souza, whilst giving a very elaborate description of the Kew instruments, dwells at length principally on the points in which they differ from those at Greenwich; but the description is here omitted, as the Kew instruments have been carefully and well described by Mr. Balfour Stewart in the volume of Reports of the Aberdeen Meeting of the British Association, p. 200–228. Prof. de Souza proceeds as follows:—]

"A short time before my visit to the Observatory Dr. Bergsma had been there, sent by the Dutch Government to examine the magnetographs destined for an observatory in Java, and constructed on the Kew pattern. I may say in passing that this examination consists in receiving practical instruction on the mode of manipulating with the instruments, in assisting in their collocation in the verification-house, and in the determination of constants. Some modifications were introduced in Dr. Bergsma's magnetographs which I will now notice, and which constitute their last state of improvement.

"The great bell-glasses which rest on the marble disks were replaced by cylinders of gun-metal surmounted by smaller glass cylinders. Each has an aperture to which is adapted a plate of glass with parallel faces, taking the place which in the great bell-glasses was occupied by the openings of the glass plate and of the achromatic lens; by this new arrangement the achromatic lens is independent of the cylinder, and can be brought near to, or removed further from, the mirror according to convenience. In this manner any disarrangement of the cylindrical glasses, or the taking of them away, does not alter the position of the lens, or interrupt the march of the magnetographs. These different pieces fit so as to enclose the magnet hermetically, and thus the air can be rarefied or withdrawn by means of an air-pump in communication with a tube which passes through the marble disk and opens into the enclosure. This exhaustion of the air prevents the influence upon the magnets of currents of air.

"Three telescopes, directed to the mirrors of the magnetographs, are established on two stone pillars, and have each an ivory scale the divisions of which are reflected, by the moveable and by the fixed mirror, into the interior of the telescope, offering in the field of view two very distinct images of the scale, one of which moves with the mirror of the magnet, so that at different times different divisions of this scale will appear to coincide with the vertical wire of the telescope. By the comparison of these divisions with that of the image which is fixed, the position of the magnet at any moment may be known; so that, besides the continuous photographic record going on out of sight, and only taken account of every other day, there may be obtained, on any occasion, *direct* observations, which is a consideration of great importance. For example, if there is a magnetic disturbance, not only can it be observed at the instant of its occurrence, but also direct observations may be obtained of oscillations which by their amplitude exceed the limits of the photographic paper.

"In describing the magnetographs at Greenwich two scales were mentioned, one elastic, the other of paper, with which the times corresponding to the different points of the base-line were obtained, and the values of the ordinates of the curves calculated. These scales at Kew are metallic, and make part of an apparatus very simple and ingenious, which, being subject to a graduated movement, is both easy and exact in operation. It is, however, not easily described without the assistance of a figure.

"For absolute determinations and secular changes there is a detached building of wood (copper-fastened) at a distance from the Observatory, where there are three wooden pillars solidly fixed in the ground, one for the instruments with which the coefficients of temperature and of induction of the magnetic bars are determined, and two for the inclinometer of Barrow and the unifilar of Gibson. These two instruments and a good chronometer constitute the necessary furniture of this building."

After a very careful and detailed description of the inclinometer and unifilar, Prof. de Souza proceeds, in his account of his first visit to Kew, as follows:—

"In the verification-house, sixty yards from the observatory, Mr. Beckley was setting up for trial for the first time the registering electrometer of Professor Thomson of Glasgow. This new invention, which seems destined to supply a great desideratum in meteorology, would have been one of the objects of the greatest interest to me, if I could have seen it in action and have appreciated some of its results. Dispersed as were its different parts, I could not well make to myself a clear idea of the whole. The following is what I gathered from the explanations of Mr. Beckley.

"Professor Thomson's electrometer has for its object the photographic registration, by the system of Brooke, of variations in the difference between the electric tension of the atmosphere and of the earth. A semicircle of brass communicates with the earth; another semicircle of the same metal is insulated from the earth, and is in communication with the external air by means of the water of a reservoir, which is thrown into the air in a constant jet. From the top of the discontinuous circle formed by these semicircles, and in the direction of the space which they leave between them, there is suspended a metallic needle insulated from the whole of the apparatus, but in communication with a Leyden jar, to which is given a constant charge measured by the angle of torsion made by another needle suspended to the thread of another apparatus. With the first needle there moves a small mirror, on which falls the light of a lamp reflecting upon the registering cylinder where the electric curve is produced upon sensitive paper. Another fascicle of light which comes from the fixed mirror gives the base-line. One of the semicircles being in the state of the earth's, and the other in that of the atmosphere's electric tension, and the needle which moves at the top of the space which separates them having a known and constant electricity, it is clear that the slightest alteration in the difference between the tensions, or in the quality of the electricity by which they are produced, will be directly indicated by the movement of the needle which impresses itself immediately on the photographic paper. If this instrument receives at Kew the attention of which inventions conducing to the advancement of science are there thought worthy, and if any imperfections which may be discovered in it in practice are successfully removed, Professor Thomson will have the honour of having discovered the most sensitive and instantaneous electrometer in existence, which will doubtless smooth the great difficulties which impede the advance of the science of atmospheric electricity. In the presence of this electrometer the electric apparatus employed at Greenwich will fall into disuse, as it has already done at Kew, where it is dismantled. Of the other meteorological instruments in the Kew Observatory, I will only mention the great standard barometer, or rather the process by means of which its large tube is filled. The barometer and a cathetometer, with which are observed the differences of level of the indices of the mercury in the cistern and in the column, are fixed to a wall which formerly supported the mural gradient of the Astronomical Observatory. It is essentially the barometer of Regnault; but it can turn around its axis, which is adjusted in the vertical position by means of screws of pressure: the indices move until they touch the surface of the mercury of the cistern; one terminates in an edge, the other in a cone: the diameter of the tube is 1·1 inch."

Prof. de Souza here describes in considerable detail the process of making and filling such a barometer-tube. [For this process the English reader is referred to Mr. Welsh's original paper in the Philosophical Transactions for 1856, Art. XXIII.]

Before returning to London, Prof. de Souza visited the Gardens at Kew, and takes occasion to express his very great admiration of the gardens, the palm-house, and especially of the museum. He then proceeds as follows:—

"In London I addressed myself to Major-General Sabine. I have great satisfaction in declaring thus publicly, that the relations acquired with this courteous gentleman so long engaged in magnetical science, constitute one of the most valuable acquisitions which I made in England. It is known that General Sabine has devoted himself for almost half a century, with an ardour and activity never interrupted, to the study of terrestrial magnetism. From 1818 to 1822 he made four successive long scientific voyages; in 1837 he published the first general map of the isodynamic lines of the globe; afterwards he brought about the establishment of four observatories very differently circumstanced in regard to the intensity of the terrestrial magnetic force, and in opposite positions in regard to the magnetical and geographical poles and equators—*i. e.* the observatories of Toronto, Hobarton, Cape of Good Hope, and St. Helena. He has also superintended these establishments, and reduced and analysed their observations, from whence have resulted numerous and important publications. He continues himself to observe during a portion of the year, and has almost completed a map of the different magnetic elements over England.

"As was to be hoped, General Sabine heard with lively interest that the establishment of a magnetical and meteorological observatory at Coimbra was in contemplation, and readily offered to help forward the realization of this good idea by directing the construction of the magnetic and other instruments required, and also undertook that they should be verified and their constants obtained at the Kew Observatory, where I should be enabled to make practical studies, and receive suitable instruction for their establishment and manipulation,

"General Sabine, speaking of the University of Coimbra in terms very agreeable to a Portuguese auditor, expressed satisfaction at so good an opportunity of sending to this respectable Academy eleven large volumes of observations analysed by him and published, under his superintendence, by the English Government. Besides the observations of the four observatories above mentioned, there are also contained in these volumes observations from Lake Athabasca, Fort Simpson, Fort Carlton, Fort Confidence, the Falkland Islands, and Pekin.

"I informed the Faculty at their first meeting after my arrival at Coimbra of the courtesies received from this *savant*, and I presented to your Excellency at the proper time the books of which I was the bearer."

Prof. de Souza then proceeds to consider the results of his journey, and its bearing on the establishment of his own hoped-for observatory. Having obtained permission to employ the funds available in the current year in the purchase of magnetic instruments, he wrote to General Sabine, asking him to bespeak for him both the self-registering instruments, and those for absolute determinations (as will be specified in the sequel), with any further improvements that he might deem desirable. He had previously consulted General Sabine on an important question, that of the choice between the different dimensions of the magnets in use at Greenwich and at Kew, and says that "the instructive reflections so obtained" had left him "completely satisfied in determining for the Kew dimensions."

In regard to the locality, it appears that the University of Coimbra does not possess any building suitable and available for the purpose; but the Rector pointed out a site which appeared to M. de Souza highly suitable, if he could assure himself that the ferruginous particles contained in the new red sandstone rock would not be objectionable. He sent specimens of the rock (a well-known one in England) through the Portuguese Ambassador to London, and experiments made with them discovered no sensible magnetic action. But although this doubt was thus satisfactorily removed, unfortunately the site in question is private property, and means are wanting both for its purchase and for the building. He presses on the authorities the urgency of this provision being made without further delay, and states that the plan proposed, after full consultations, and for which Mr. Beckley has offered to make the drawings, combines the greatest economy with all that can be desired scientifically. Finally, he discusses the question of meteorological instruments, and concludes for obtaining them also from England, proposing to devote to this purpose the means at his disposal up to the termination of the University year in 1862.

Second Visit to the Kew Observatory.

Hearing on the 5th of July (1861) from General Sabine that the magnetic instruments were nearly ready for trial and verification, he proposed to devote his approaching holidays to profit by the opportunity of gaining practical instruction and experience in their use; proposing at the same time to study Professor Thomson's electrometer—the only apparatus, he says, which holds out the hope of satisfying the present exigences of science, which require continuous registration—and to obtain the other meteorological instruments and compare them with the Kew standards.

The first part of the report is dated July 25, 1861; the second part November 16, 1861, and gives an account of his second visit to the Kew Observatory. It is prefaced by acknowledgements of the kindness and help he received from Messrs. Stewart and Chambers at the Observatory, from General Sabine, Mr. Gassiot, and the whole of the "directing Committee," from the British Association, and from the Royal Society.

He arrived in London on the 24th of August, and finding General Sabine absent in Wales, proceeded at once to the artists, Adie, Barrow, and Gibson, who informed him that his instruments were at Kew, whither he lost no time in repairing, and where the Director arranged that the work should begin at once. Prof. de Souza took up his abode at Richmond, and went daily to the Observatory, remaining there from 9.30 A.M. to 5.30 P.M. He speaks of the great kindness, instruction, and constant assistance which he received from the Director and the whole personal staff of the Observatory, in their different degrees and functions, in the practical study of the instruments. This study consists, he says, in setting them up in the trial house precisely as they are to be set up at Coimbra, in determining their constants, in repeatedly observing the magnetic elements with them and comparing the results with those of the Observatory, and in reducing these observations. In the course of the observations some little faults, which would otherwise have escaped notice, were discovered in the instruments; to correct these the artists were repeatedly called to Kew, or the Director conferred with them in London.

The collection of magnetic instruments consists, *firstly*, of the magnetographs which register continuously the horizontal force, the vertical force, and the declination; and, *secondly*, of the portable instruments, viz. Barrow's circle for the absolute determination of the inclination, with the apparatus for determining the total force by Dr. Lloyd's method; and the unifilar, by Gibson, with its apparatus for the absolute determinations of the declination, and of the horizontal force by the method of vibrations and deflections.

The magnetographs are accompanied by three telescopes, for the direct observation of the magnetic elements when requisite, and by all things necessary for beginning work as soon as they are established—utensils for photographic manipulation, a year's supply of chemical ingredients, waxed paper, spare bell-glasses, chimneys and mirrors, coloured glasses for the photographic house, &c. The portable instruments, which are indispensable in an observatory, being also proper for the observations of a magnetic survey, are conveniently packed in portable boxes, and accompanied by a tripod stand.

The existence of the Astronomical Observatory at Coimbra makes it possible to dispense with a transit-instrument and clocks, but a good chronometer is essential; and by the kind aid of the Hydrographer, Admiral Washington, to whom General Sabine wrote on the subject, Prof. de Souza received permission to purchase one of those examined at Greenwich, and guaranteed by the Astronomer Royal, at the price which would be paid for the same by the British Admiralty.

"Besides the barometer required for the ordinary direct observations," Prof. de Souza desired an absolute standard such as is at Kew. So large a tube could neither be filled by the ordinary method, nor, of course, transported full. The course taken was therefore to learn at Kew how to perform the filling process by Mr. Welsh's method, so as to put it in practice at Coimbra. The experiment was made with two glass tubes of ordinary size, of which Prof. de Souza filled and closed one in the proposed manner, and Mr. Casella the other, with equal success.

Prof. de Souza then ordered from Mr. Casella two tubes of large dimension, very clean and the air exhausted, with the cistern and all the appurtenances of the barometer to be made with one of them. If he succeeds, according to his hopes, as he did at Kew, Coimbra, he says, will possess an absolute standard, which will be the standard for Portugal as that of Kew is for England. But he proposes not to order the cathetometer until the tube is actually filled and raised into its proper position. He then gives the list of the other meteorological instruments, all verified at Kew.

"A standard thermometer graduated in divisions of 0·2 Centigrade. It was one of the best old tubes in the possession of the Observatory, only wanting the graduation, which was skilfully performed under my sight by the young George Whipple, assistant at the Observatory.

"Two psychrometers with divisions of 0·5 Centigrade.

"A maximum registering thermometer on Professor Phillips's principle.

"A minimum registering spirit thermometer.

"A minimum registering mercurial thermometer; a recent invention of Mr. Casella, which was tried at Kew with a good result, and may be advantageously substituted for the spirit thermometer, of which the defects have long been recognized by meteorologists.

"A Herschel's actinometer.

"A spirit thermometer for registering terrestrial radiation, with a suitable parabolic mirror.

"Two rain-gauges.

"A vaporimeter with the corresponding pluviometer."

With the above, and a pluviometer and hygrometer of Regnault, and an anemograph by Salleron belonging to the Cabinet de Physique at Coimbra (which requires to receive some modifications), Prof. de Souza considers that an equipment is provided for immediate work, contemplating eventually the addition of "apparatus for the continuous registry of barometric and thermometric variations, the cost of which will be under £120."

The continuous registry of atmospheric electricity by the photographic process must be given up for the present: Professor Thomson's electrometer, excellent in principle, leaves, however, somewhat to be desired in practice. Prof. de Souza examined the one at Kew with great attention, watching its march carefully, and afterwards having it taken to pieces; and he is of opinion, as is also Mr. Stewart, that slight modifications would obviate some of the defects to which it is liable.

Mr. Beckley has drawn a plan and elevation for the Observatory at Coimbra, which is submitted to the Council of the University: it provides both for the instruments which have been ordered, and for such as may, it is hoped, be subsequently acquired, these being a barograph and thermograph; and possibly hereafter a photo-heliograph for obtaining images of the solar spots, especially with a view to their supposed relations to magnetic phenomena. The cost of a photo-heliograph would now be about £80. In a few years many improvements will probably be made in it, and meantime what is wanted for this particular object may be supplied by observations of the solar spots with an ordinary telescope, or by data obtained by the Astronomical Observatory as part of its own work.

Besides the excellent collection of magnetic instruments (one of the finest and most complete in existence, with scrupulously determined constants) which is thus placed in the possession of the University of Coimbra, Prof. de Souza has blank forms for the record of all the observations, and the formulæ for their reduction, collected both from the instruction given to him at Kew, and from his own careful examination of the manuscript books of the Observatory.

The magnetic instruments have arrived safely at Coimbra, and measures have been taken for the similar conveyance of the meteorological instruments.

Mr. Beckley's drawings furnish all the data for the construction of the building, which will be simple and of small cost. An estimate, M. de Souza says, is appended; but it does not appear in the printed report.

M. de Souza further alludes to his having reported, both to the University and to the Government, his attendance at the Meeting of the British Association at Manchester, as a member of its Committee of Mathematics and Physics, where he was enabled to enter into relations with the distinguished men assembled there from all parts, some of whom were Directors of Observatories, who promised the accounts of their results, and would doubtless expect his. The British Association has granted a complete copy of their annual Reports from the commencement, and with these and the works previously received, the Coimbra establishment would find itself at once in possession of a good library of the best writings on the subjects of its investigations. He once more recalls all the kindness and assistance he received in England, adding that the Royal Society granted £30 from their "Donation-fund" for the expenses of the verification of the magnetic instruments prepared for the Coimbra Observatory, and concludes by urging the completion of the arrangements for an establishment which he trusts will prove alike honourable to his University and to his country.

Report on the Dredging of the Northumberland Coast and Dogger Bank, drawn up by HENRY T. MENNELL, *on behalf of the Natural History Society of Northumberland, Durham, and Newcastle-on-Tyne, and of the Tyneside Naturalists' Field Club.*

THE Committee to whom the grant of the Association for "Dredging on the Dogger Bank and the coasts of Northumberland and Durham" was entrusted having, at the request of the Natural History Society of Northumberland, Durham, and Newcastle-on-Tyne, and of the Tyneside Naturalists' Field Club, courteously committed the practical carrying out of the proposed investigations to these bodies, their members contributed the large sum required in addition to the Association grant, and I have now to report the result of our labours.

The dredging took place at the end of August; hence the time which has since elapsed has been too limited to do full justice to the specimens obtained in many departments.

It was confined to the following localities: 1st, on a line due east of Tynemouth, extending to the Dogger Bank, a distance of about 100 miles.

The dredging commenced about twenty miles from land, was resumed at about fifty miles from land, and continued at intervals of about five miles for the remainder of the distance.

The depth of water never exceeded 40 fathoms, and ranged chiefly from 25 to 35 fathoms, the bottom being mainly composed of fine sand and ooze.

On the second cruise, the coast twenty miles off Coquet Island, and twenty to thirty miles off Berwick, was thoroughly dredged; in the latter locality the water attained a depth of 55 fathoms, being the deepest we possess off the Northumberland coast. The bottom consisted of coarse sand and gravel.

The vessel employed was a steamer.

The following gentlemen have, at the request of the two Societies, prepared lists of the specimens obtained, and are responsible for the determination of the species, viz.:—

Mollusca (except Tunicata),	Mr. H. T. Mennell.
Mollusca Tunicata,	Mr. Joshua Alder.
Crustacea,	Rev. Alfred Merle Norman.
Pycnogonoidea,	Mr. George Hodge.
Echinodermata,	Mr. George S. Brady.
Polyzoa, Hydrozoa, Actinozoa,	Mr. Joshua Alder.
Foraminifera,	Mr. Henry B. Brady, F.L.S.

The results, as arrived at by these gentlemen, are summarized below.

Of Mollusca 136 species were obtained, viz.:

Cephalopoda	1		Proso-	Opistho-	Nudi-branchiata.
Gasteropoda	64	=	51 +	7 +	6
Lamellibranchiata	60				
Brachiopoda!	0				
Tunicata	11				
	136				

No species new to science was obtained, and but one previously unrecorded as British. This is the *Cynthia glacialis* of Sars, two specimens of which had been previously obtained by Mr. John Stanger on the Northumberland coast, and noticed in the Tyneside Club Transactions under the provisional name of *Cynthia vestita* (Alder). It has since been ascertained, however, that Professor Sars had taken the species on the Norwegian coast, and published it in 1858 under the name we now adopt.

Four other species were added to those recorded in Mr. Alder's excellent "Catalogue of the Mollusca of Northumberland and Durham," published in the 'Tyneside Club Transactions,' viz. *Rissoa sculpta* (Forbes and Hanley), new to the east coast of Britain, *Eulima nitida* (Lamarck), *Eulima gracilis* (Alder, MS.), and *Syndosmya intermedia*.

Several species hitherto considered to be of great rarity on our coast were obtained in some plenty, *e.g.* *Trophon Barvicensis*, *Mangelia Trevelyana*, *Chemnitzia fulvocincta*, *Scalaria Trevelyana*, *Trochus millegranus*, *Puncturella Noachina*, and *Lucina flexuosa*. Of the rarer species previously recorded, there were found, but not abundantly, *Mangelia teres*, *Natica Grœnlandica*, *Philine quadrata*, *Cylichna strigella*, *Crenella decussata*, and *Neæra cuspidata*. Of the special varieties of the Dogger Bank which have hitherto only been taken on the fishing-lines, the only trace obtained was a single capsule of *Fusus Turtoni*. Further efforts are therefore required to ascertain the exact habitat on our coast of the rare larger *Fusi*, of *Buccinum* (?) *Dalei* and *Pano-*

pæa Norvegica. When this is discovered we may expect to find associated with them many interesting Boreal species, perhaps too small to have attracted the attention of the fishermen.

Some interest attaches to the subfossil or upper tertiary shells which were dredged in very deep water twenty to thirty miles east of Berwick. Amongst these were *Astarte elliptica* and *Mya truncata*, var. *Uddevallensis*, neither of which have been found living on our coast, and *Margarita cinerea*, an extinct species, which has been recently dredged under similar conditions in other localities.

The whole of the Crustacea which were obtained have not as yet been examined; but among those already determined are many of great interest. In all about 90 species were dredged. Among the Podophthalmia, mention may be made of *Inachus Dorsettensis* as new to the N.E. coast of England, and of *Crangon spinosus*, *bispinosus*, and *Allmanni*. The last of these, a recently distinguished species, was abundant both off the Durham and Northumberland coasts. From several specimens of *Hippolyte securifrons* which were obtained, Mr. Norman is enabled to correct an error in the specific character which he gave at the last meeting of the Association, from the Shetland type specimen. He finds that there are four instead of three pairs of spines on the front margin of the carapace, two spines being placed together over each orbit.

Both sexes of *Mysis spiritus* (Norman), only previously known from three or four females taken near Hartlepool, were dredged in considerable numbers; and also an undescribed species of the same genus, which Mr. Norman thus describes:—

"*Mysis didelphys* (Norman, n. sp.).

"Antennal scale lanceolate, twice as long as the eye, two-jointed, ciliated all round; the second joint very short, with a rounded apex terminating in five cilia. Telson entire, not more than two-thirds the length of the intermediate, and half the length of the external laminæ of the tail; lateral margins of telson armed with ten spines, some of which are situated quite at the base; apex with a large spine at each corner, but no central intermediate spines.

"This is a much stouter species than *Mysis vulgaris*, to which it is nearly allied. The antennal scale is less produced; and the second joint is much shorter, and terminates in five cilia instead of in an acutely pointed spine. The telson is likewise shorter, with fewer lateral spines, and without the two intermediate apical spines which are present in *M. vulgaris*. *Mysis didelphys* was dredged in deep water, forty miles off the coast, while the habitat of *M. vulgaris* appears to be invariably the brackish waters of estuaries and salt-marshes."

The curious and abnormal family of the Diastylidæ was well represented by *Diastylis Rathkii*, *Eudora truncatula*, *Vaunthomsonia cristata*, and three undescribed species. These are thus named and described by Mr. Norman:—

"*Cuma rosea* (Norman, n. sp.).

"Last five segments of the thorax uncovered by the carapace. No abdominal legs. Carapace unarmed above and below, rounded in front. Telson well developed, as long as the basal portion of the caudal appendages, furnished with two spines on each side, and having the rounded apex closely surrounded by seven subequal spines. Colour white, mottled with rosy spots. Dredged 50–60 miles east of Tynemouth.

"*Cyrianassa elegans* (Norman, n. sp.).

"Only three pairs of abdominal legs, which are the appendages of the first three segments. Telson produced, as long as the basal joints of the caudal appendages, armed with a spine on each side and eight spines around the extremity. Deep water off Tynemouth.

"*Cyrianassa ciliata* (Norman, n. sp.).

"Carapace hispid, truncate in front, and furnished with a toothed process on the antero-lateral margin. Lower antennæ longer than the body. Five segments of the thorax uncovered by the carapace. Abdominal legs, two pairs, attached to the first two segments. Telson short, one-third the length of the basal joint of the lateral appendages, with a rounded unarmed extremity. Caudal appendages furnished with plumose cilia, which are remarkably long on the outer branch. Deep water off Tynemouth."

Among the more interesting Amphipoda obtained were *Montagua Alderii* and *pollexiana*, *Callisoma crenata*, *Anonyx denticulatus*, *Ampelisca Gaimardi* and *Belliana*, *Phoxus plumosus*, *Iphimedia obesa*, *Acanthonotus testudo*, *Atylus bispinosus*, *Microdeutopus anomalus*, *Caprella lobata*, *Dexamine Vedlomensis*, *Kröyera altamarina*, and *Melita proxima*. Of the last three species only the type specimens were previously known.

Two Entomostraca were dredged which are new to the British fauna, *Cypridina globosa* (Liljeborg) and *Ichthyophorba hamata* (Liljeborg), and a third, new to science, thus described by Mr. Norman:—

"*Cythere limicola* (Norman, n. sp.).

"Carapace-valves slightly quadrilateral, front margins oblique, greatest height at the anterior third. Sculptured with two elevated, longitudinal, slightly curved parallel lines on the lower half of the valves, from the anterior extremity of which a transverse elevated line passes to the hinge-margin, where it terminates in a large tubercle. Two similar tubercles close together near the hinder extremity of the hinge-margin."

Among the other Entomostraca were *Nebalia bipes*, *Cythere quadridentata* and *acuta*, and what is perhaps a variety of *flavida*, *Cythereis fimbriata*, *Evadne Nordmanni*, and *Anomalocera Patersonii*.

Of Pycnogonoidea (which we only separate from the Crustacea because they have been on this occasion examined by different gentlemen, and not as expressing an opinion that they should be so separated) ten species were obtained, belonging to four genera, *Pycnogonum*, *Phoxichilidium*, *Pallene*, and *Nymphon*. Of these, two are new to Britain and two are new to science; the latter are thus described by Mr. George Hodge:—

"*Pallene attenuata*, n. sp., Hodge.

"Rostrum thick, constricted at the base, swollen near the middle, and rounded at the apex. Legs long, sparingly hispid; first, second, and third joints short, the second the longer; fourth rather stout, and as long as the second and third united; fifth and sixth slender, and about the length of the fourth; seventh very short; eighth convex on the outer margin, straight on the inner, with a few short hairs scattered along both margins. A *single* claw at the extremity, which, when pressed against the limb, reaches to the junction of the seventh joint. Foot-jaws long and slender, projecting considerably beyond the end of the rostrum. Anterior portion of thorax attenuated, and advanced nearly in a line with the tip of the rostrum, where it slightly bulges and gives origin to foot-jaws, immediately behind which is seated the oculiferous tubercle, which is long and narrow. Abdomen long, rounded at apex, slightly tapering to base. At the origin of each leg on the dorsal aspect is a large wart-like protuberance.

"*Nymphon brevirostris*, n. sp., Hodge.

"Rostrum short and stout; foot-jaws thick, divergent, second joint or hand nearly as long as the first; palpi five-jointed, brush-like, first and second joints long and nearly of the same length, either of them equal to the three terminal joints, the last of which is the shortest. Thorax robust. Abdomen stout and conical. Oculiferous tubercle midway between the first pair of legs. Legs stout, sparingly furnished with stout spine-like hairs; first and third joints short; second slender at its origin, swelling upwards; fourth and fifth joints each as long as the first three; sixth much longer, and slender; seventh short; eighth long, slightly bent, furnished along its inner margin with a few short spines, and terminating in one moderately large and two small claws."

Two species of *Nymphon* new to Britain were also taken, viz. *Nymphon hirtum*, O. Fabr., and *N. brevitarse*, Kröyer.

The rarity of male Nymphons is singular; none were obtained during the expedition, although the number of females was considerable: on the contrary, the males of *Pycnogonum* were abundant, and the females rarely seen. This seems to be the usual experience of collectors.

The researches of Mr. Hodge into the development and structure of the Pycnogonidæ have led him to place them with the Entomostraca, as an order of that subclass, *Arachnopoda* or *Pycnogonoidea*.

A great number of Annelids were dredged, but these have not yet been catalogued; we trust, however, next year to present a satisfactory list of these animals. *Sipunculus Bernhardus* was one of the most abundant species, occupying every dead Dentalium which was brought up. It may be remarked also that in the deepest water dredged, that is, off Berwick, the dredge showed the bottom to consist almost entirely of fragments of the deserted tubes of these creatures. Few opportunities existed of obtaining Entozoa; those that did occur were not neglected, but the number was so meagre that no list has been attempted.

Of Echinodermata we dredged twenty-seven species; amongst these is one species of *Ophiura* hitherto undescribed, of which Mr. G. Hodge, who had a short time before taken it on the Durham coast, gives the following description:—

"*Ophiura Normani* (n. sp., George Hodge).

"Disk either pentangular or round, the former pertaining to well-grown, the latter to young specimens. Upper surface of disk rotulated, under surface corresponding with that of the other members of the genus. Two clasping scales at the origin of each ray, each bearing about ten short spines. A crescent of eight or ten short blunt spines on the upper surface of the rays, close to the disk. Lateral ray-plates bearing five moderately long spines. Upper ray-scales nearly square, slightly tapering towards the disk. Rays about four times as long as the diameter of the disk, which in well-grown individuals measures about $\frac{1}{4}$ of an inch. Colour reddish yellow, occasionally of a pale sandy tint."

The Rev. A. M. Norman has also taken a single specimen of this species in the Clyde, and three or four in the Shetlands.

Bryssus lyrifer, a species previously considered to be of much rarity on the coast, was met with in great plenty and of unusual size; still more abundant were *Spatangus purpureus* and *Amphidotus roseus*.

All the species of Ophiuroidea, Asteroidea, and Echinoidea were much more plentiful on the muddy ground which lies immediately within the Dogger Bank than elsewhere.

Uraster rosea, a fine species not before met with on the east coast, was added to the local fauna.

Among the Holothuridæ, several specimens of a small *Thyonidium* were dredged in Berwick Bay, which appear to be the *Holothuria pellucida* of Müller, and not the *Cucumaria hyalina* of Forbes, the latter of which appears to belong to the genus *Thyone*. Should a further examination confirm this view, the species is new to Britain.

Thyonidium commune was also added to our *local* fauna.

No Zoophytes were obtained previously unrecorded in Mr. Joshua Alder's "Catalogue of the Zoophytes of Northumberland and Durham," published in the 'Transactions of the Tyneside Club;' nevertheless the list is a good one, containing as it does 77 species, viz.—

Polyzoa	27
Hydrozoa	40
Actinozoa	10
	77

Among the Polyzoa, *Menipea ternata* and *Cellularia Peachii*, two northern deep-water species rare on other parts of the English coast, were procured in considerable abundance. Of *Bugula Murrayana* and *B. fastigiata*, also northern forms, only two or three specimens were obtained.

Among the Hydrozoa the most noteworthy is *Sertularia fusca*, a species peculiar to the north-eastern coasts of England and to Scotland. *Sertularia pinaster* was also met with, and *S. tamarisca* with female capsules.

The Medusidæ are not included in Mr. Alder's Catalogue just referred to, and of these very few species were identified.

A very fine and strikingly beautiful *Medusa* was, however, taken some seventy or eighty miles from the coast, which appears not to have been hitherto met with in our seas; nor, indeed, have we seen the description of any genus to which it would seem to be assignable.

The Rev. A. M. Norman describes it as follows:—

"The hydrosoma is inverted cup-shaped, moderately convex, about 4½ inches in diameter, tinged with deeper and paler shades of indigo-blue.

"The margin is divided into eight major lobes, each of which is subdivided into four minor lobes, making thirty-two lobes in all. The disk of the hydrosoma is elevated into sixteen radiating ridges, alternating with as many intermediate furrows. A radiating canal, of an intenser blue than the rest of the hydrosoma, passes down each of the ridges; and these radiating canals terminate in the deeper sinuses of the margin and in the central sinuses of the major lobes, while each furrow is traversed by a white vessel whose distal extremity is situated at one of the intermediate sinuses of the major lobes. Numerous transverse branches proceed from the blue and elevated canals, and pass down the slopes of the ridges to the base of the furrows. These transverse vessels are recognized by the deeper tint of blue which marks their course.

"There are no tentacles on the margin of the disk; but, situated a short distance within the margin, opposite each of the greater sinuses, there is seen a semicircle of about forty pale-yellow simple tentacles, which are so short that they scarcely hang below the margin of the disk. The horns of the semicircle of tentacles point outwards.

"There are eight eyes, which are placed at the centre of the major lobes, on the blue canal, at a short distance from the margin.

"The oral appendages are greatly developed in the form of four (?) large, many-folded, ochreous-yellow curtains, exquisitely margined with a short, finely-cut fringe. The length of the curtains, as they hang suspended in the hydrosoma, is somewhat greater than their united breadth.

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"*The ovaries.*—I take it that the brownish-pink masses which were seen suspended just outside the curtains in the living animal were the ovaries, but, not having had the opportunity of examining these bodies, I hesitate to state that they actually are the reproductive organs."

The specimen described has been well preserved in a mixture of diluted spirit and creosote.

In Actinozoa our list is not rich; *Stomphia Churchiæ* (Gosse), and a *Phellia* not yet ascertained, but probably the *Phellia gausipata* of Gosse (a species hitherto only taken at Wick), are among the rarer species obtained.

The list of Foraminifera is a very rich one, considering the short time and the limited area over which the dredging extended.

Of the 101 species and varieties enumerated in Prof. Williamson's monograph, our list contains 55; and besides these, several are reserved for further examination.

Fully twenty of these had not previously been found on our coast by Mr. Joshua Alder or Mr. H. B. Brady, the only observers.

The most noticeable facts respecting the Foraminifera obtained are, first, the extraordinary prevalence of the various forms of *Dentalina* in the Berwick Bay dredgings, occurring as they do in every gradation from the extreme form of *Dentalina subarcuata* to the extreme of *D. legumen.* No line of demarcation can be drawn between the hyaline shell constricted at the septa (the septal lines being oblique) and the more robust, much-curved form of *D. legumen.* On the same ground *Polymorphina* frequently assumes the more luxuriant form known as variety *fistulosa.* And secondly, the number and beauty of the *Lagenæ*, of which every British variety was taken, most of them abundantly.

Of the Sponges no list has been attempted, the very few species obtained waiting further examination.

Altogether, the results are, I trust, such as to justify further efforts on the same coast; and they are, at any rate, most interesting to our local naturalists, who are, through the medium of the Tyneside Naturalists' Field Club, working out the fauna of the district with a completeness which few districts can equal.

Report of the Committee appointed at Manchester to consider and report upon the best means of advancing Science through the agency of the Mercantile Marine. By CUTHBERT COLLINGWOOD, *M.B., F.L.S.*

THE Committee appointed at the Manchester Meeting of the British Association consisted of the following gentlemen:—

Dr. Collingwood, Liverpool.
R. Patterson, F.R.S., Belfast.
John Lubbock, F.R.S., London.
J. Aspinall Turner, M.P., Manchester.
P. P. Carpenter, Ph.D., Warrington.
Rev. H. H. Higgins, M.A., Liverpool.

Since that time much has been done in promoting the scheme suggested in the paper then read before Section D. That paper has been printed in the 'Proceedings of the Literary and Philosophical Society of Liverpool,' and copies of it have been struck off, and very largely circulated among shipowners, merchants, and all the large and influential list of correspondents to whom the documents of the Mercantile Marine Association of Liverpool are usually forwarded. I have also forwarded copies to all whom I know to be interested in the subject, and, in the volume of Proceedings, it has passed to all the scientific societies in correspondence with the Liverpool Literary and Philosophical Society. Mr. Robert Patterson, of Belfast, has brought the subject under the notice of the shipping interest and the Natural History Society of that town; and many copies have been circulated in America through Captain Anderson (of the R.M.S.S. 'China'), Professor Agassiz, and Mr. Wm. Stimpson of the Smithsonian Institution. Among those to whom I forwarded copies of the paper was Mr. E. Newman, who reprinted it in the 'Zoologist' for July and August 1862. The subject has thus been brought fairly before the mercantile and scientific public, and the attention of a large number of persons has been directed towards it—the general opinion being decidedly in its favour, on the score of advantages to be derived at once by science and by philanthropy.

In the autumn of 1861, in conversation with Earl Granville, Lord President of the Committee of Council on Education, I had an opportunity of bringing the subject under his Lordship's notice, and of explaining to him the advantages which we proposed to ourselves from this scheme, well knowing the important assistance which his Lordship might afford in case of its meeting with his approval. He expressed an interest in the matter, and desired to be further informed upon it. On the publication of the paper, therefore, at his Lordship's request, I sent him a copy, and shortly after received the following communication:—

" Science and Art Department of the Committee of
Council on Education,
South Kensington, London, W., Jan. 30, 1862.

" Sir,—I am directed by the Lords of the Committee of Council on Education to request that you will be good enough to furnish me with twenty copies of your pamphlet 'On the Opportunities of Advancing Science enjoyed by the Mercantile Marine,' to send to all the Navigation Schools under this department.

" I am, Sir,
" Your obedient Servant,
" Norman M'Leod,
" *Assistant Secretary.*

" *Dr. Collingwood,*
15 *Oxford Street, Liverpool.*"

The next important advance was as follows:—It being considered of the last importance that the sanction and cooperation of shipowners should be obtained, a meeting was convened in the mayor's parlour, Town-hall, Liverpool, at which some of the most influential shipowners of that port, as well as the chairman and secretary of the Mercantile Marine Association, were present; Mr. T. M. Mackay (a gentleman ever ready to cooperate in every scheme for the good of seamen) occupying the chair. The meeting having been informed of the nature and progress of the movement, and the subject having been discussed, the gentlemen present promised their support, both nominal, and pecuniary if it were required.

Believing that much might be effected by associating merchant-officers with existing scientific societies, in an honorary manner, the reporter, as Secretary to the Liverpool Literary and Philosophical Society, brought the matter before the council and members. This Society, established in 1812, has just celebrated its fiftieth anniversary, and is the oldest scientific society in Liverpool. An addition to the laws was duly passed and confirmed, to the effect that the Society " be empowered to elect as *Associates* masters of vessels or others engaged in marine pursuits, who may have peculiar facilities for adding to the scientific interest of the Society's proceedings; such Associates to be in every case recommended by the council, and to have the same privileges as honorary members—their number to be limited to twenty-five." This plan, there is little doubt, may be productive of much good, and it is hoped will be adopted by some other societies. It offers a stimulus to the intelligent shipmaster, and tends to increase his self-respect, by showing that he is held in respect by those who appreciate his efforts to advance science and his own mental culture.

Although it is hoped that in the course of time some tangible results may be obtained in several branches of science, the writer, being chiefly interested in the science of zoology, determined to make a beginning by causing to be prepared plain directions for the study and preservation of animals in all parts of the world. It being evident that, if we are to expect anything from the mercantile marine, its members should be definitely informed as to what we wish them to do, a committee of the Literary and Philosophical Society was appointed, at the writer's suggestion, to draw up such plain directions as should not fail to be sufficient for the end in view. The preparation of such a paper was entrusted to Mr. T. J. Moore, curator of the Liverpool Free Public Museum, a gentleman well qualified for the task; and having received the sanction of the Committee, the paper was published as an Appendix to the 'Proceedings of the Literary and Philosophical Society' for 1861–62. It is entitled, "Suggestions offered on the part of the Literary and Philosophical Society of Liverpool to Members of the Mercantile Marine who may be desirous of using the advantages they enjoy for the promotion of Science, in furtherance of Zoology," pp. 51. This pamphlet, containing full directions for the preparation of all kinds of animals, methods of study, and lists of text-books and useful apparatus, has been separately published by the Society, for distribution in quarters where it is likely to prove useful. It is desirable that such manuals for other sciences should be also carefully compiled, in order that every intelligent seaman may have scope to exercise his talents in whatever direction his own tastes may conduct him; and thus, there can be no doubt that a useful and valuable body of scientific information would be collected to aid the researches of men of science at home.

It is much to be regretted that a united body of members of the mercantile marine, such as the Mercantile Marine Service Association of Liverpool, should not enter cordially into a scheme which they have themselves acknowledged to be one fraught with usefulness. Had the executive council of this Association shown an ordinary interest in its progress, still greater advances would already have to be recorded; but the writer is sorry to have to report that he has not met with that assistance and cooperation from that body which he felt entitled to look for. Although from the first invited to cooperate in the plans proposed, no steps have been taken by them, beyond the tardy publication of some valuable suggestions urged upon them by one member of the council (since resigned) and one of the most intelligent members of the service. This lukewarmness of a body of men who, by their example, might be of the most material assistance is likely to retard, although not to destroy, the prospects of the scheme; and could the services of a small and active committee of influential gentlemen be secured, success must ultimately crown their efforts.

There can be no doubt whatever that it is to the rising generation of seamen that we must chiefly look for the fruits of any scheme of improved

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education which may be adopted in the present day, and such establishments as the 'Conway' training-frigate in the Mersey are powerfully useful to that end; still, in order to collect together the elements of scientific industry and laudable ambition, which doubtless exist, scattered among the present body of merchant-seamen, it is desirable, as a beginning, to offer a certificate of merit to such commanders and other officers as hold the extra certificate of the Marine Board, or who keep the meteorological log-book supplied by the Observatory, or who show in various other ways a desire to improve their minds and to encourage industry in those under their charge. It must strictly be borne in mind, however, that the sea is the only place where the *sailor's* mind can be properly influenced. Churches, schools, and sailors' homes on shore are only attended by those whom better influences *at sea* have inclined for good. Masters of vessels, therefore, who encourage their apprentices to continue their studies at sea, and who open schools for the purpose of teaching those who have had no benefits of education on shore, are in the first place well deserving of some reward, such as a certificate of merit, which should be so constructed and signed as to carry some weight. The nature, therefore, of this certificate, and by whom it should be signed, are questions of great importance to the success of the movement, and would require mature consideration. If the Committee of Council on Education or the Board of Trade, or both, could be induced to take an active and official interest in the matter, the difficulty would be at once solved.

It should be mentioned, as a practical encouragement of some value, that the Colonial and Continental Church Society (9 Serjeants' Inn, Fleet Street) has, through Captain Anderson, offered to grant libraries for sailors afloat, on the following conditions:—1. The Council of the Mercantile Marine Service Association are to recommend to them four captains each year, to each of whom the above Society will grant a library, value £5. 2. It will be understood that it is desirable to select such captains as have communication with our colonial possessions.

Enough has now been said and done to prove that there is a current at work, setting in the right direction; and we can only now leave the matter to time, feeling fully assured that it will go on, and bear ultimate fruit, both in the advancement of science and in the elevation of the character of the merchant-seaman.

Provisional Report of the Committee appointed by the British Association on Standards of Electrical Resistance.

MEMBERS of the Committee:—Professor A. Williamson, F.R.S.; Professor C. Wheatstone, F.R.S.; Professor W. Thomson, F.R.S.; Professor W. H. Miller, F.R.S.; Dr. A. Matthiessen, F.R.S.; Mr. F. Jenkin.

THE Committee regret that they are unable this year to submit a final Report to the Association, but they hope that the inherent difficulty and importance of the subject they have to deal with will sufficiently account for the delay.

The Committee considered that two distinct questions were before them, admitting of entirely independent solutions. They had first to determine what would be the most convenient *unit* of resistance; and secondly, what would be the best form and material for the *standard* representing that unit. The meaning of this distinction will be apparent when it is observed that, if the first point were decided by a resolution in favour of a unit based on Professor Weber's or Sir Charles Bright and Mr. Latimer Clark's system, this decision would not affect the question of construction; while, on the other hand, if the second question were decided in favour of any particular arrangement of mercury or gold wire as the best form of standard, this choice would not affect the question of what the absolute magnitude of the unit was to be.

The Committee have arrived at a provisional conclusion as to the first question; and the arguments by which they have been guided in coming to this decision will form the chief subject of the present Report.

They have formed no opinion as to the second question, or the best form and material for the standard.

In determining what would be the most convenient unit for all purposes, both practical and purely scientific, the Committee were of opinion that the unit chosen should combine, as far as was possible, the five following qualities.

1. The magnitude of the unit should be such as would lend itself to the more usual electrical measurements, without requiring the use of extravagantly high numbers of ciphers or of long series of decimals.

2. The unit should bear a definite relation to units which may be adopted for the measurement of electrical quantity, currents, and electromotive force; or, in other words, it should form part of a complete system for electrical measurements.

3. The unit of resistance, in common with the other units of the system, should, so far as is possible, bear a definite relation to the unit of work, the great connecting link between all physical measurements.

4. The unit should be perfectly definite, and should not be liable to require correction or alteration from time to time.

5. The unit should be reproducible with exactitude, in order that, if the original standard were injured, it might be replaced, and also in order that observers who may be unable to obtain copies of the standard may be able to manufacture one for themselves without serious error.

The Committee were also of opinion that the unit should be based on the French metrical system, rather than on that now used in this country.

Fortunately no very long use can be pleaded in favour of any of the units of electrical resistance hitherto proposed, and the Committee were therefore at liberty to judge of each proposal by its inherent merits only; and they believe that, by the plan which they propose for adoption, a unit will be obtained combining to a great extent the five qualities enumerated as desirable, although they cannot yet say with certainty how far the fourth quality, of absolute permanency, can be ensured.

The question of the most *convenient magnitude* was decided by reference to those units which have already found some acceptance. These, omitting for the moment Weber's $\frac{\text{metre}}{\text{seconds}}$, were found to range between one foot of copper wire weighing one hundred grains (a unit proposed by Professor Wheatstone in 1843) and one mile of copper wire of $\frac{1}{16}$th in. in diameter, and weighing consequently about $84\frac{1}{2}$ grains per foot. The smaller units had generally been used by purely scientific observers, and the larger by engineers or practical electricians.

Intermediate between the two lay Dr. Werner Siemens's mercury unit, and the unit adopted by Professor W. Thomson as approximately equal to one hundred millions of absolute $\frac{\text{foot}}{\text{seconds}}$. The former is approximately equal to

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371 feet, and the latter to 1217 feet, of pure copper wire $\frac{1}{16}$th in. in diameter at 15° C. Both of these units have been adopted in scientific experiments and in practical tests; and it was thought that the absolute magnitude of the unit to be adopted should not differ widely from these resistances.

The importance of the *second quality* required in the unit, that of forming part of a coherent system of electrical measurements, is felt not only by purely scientific investigators, but also by practical electricians, and was indeed ably pointed out in a paper read before this Association in Manchester by Sir Charles Bright and Mr. Latimer Clark.

The Committee has thus found itself in the position of determining not only the unit of resistance, but also the units of current, quantity, and electromotive force. The natural relations between these units are, clearly, that a unit electromotive force maintained between two points of a conductor separated by the unit of resistance shall produce the unit current, and that this current shall in the unit of time convey the unit quantity of electricity.

The first relation is a direct consequence of Ohm's law; and the second was independently chosen by Weber and by the two electricians above named.

Two only of the above units can be arbitrarily chosen; when these are fixed, the others follow from the relations just stated.

Sir Charles Bright and Mr. Latimer Clark propose the electromotive force of a Daniell's cell as one unit, and choose a unit of quantity depending on this electromotive force. Their resistance-unit, although possessing what we have called the second requisite quality, and superior consequently to many that have been proposed, does not in any way possess the third quality of bearing with its co-units a definite relation to the unit of work, and has therefore been considered inferior to the equally coherent system proposed by Weber many years since, but until lately comparatively little known in this country.

Professor Weber chose arbitrarily the unit of current and the unit of electromotive force, each depending solely on the units of mass, time, and length, and consequently independent of the physical properties of any arbitrary material.

Professor W. Thomson has subsequently pointed out that this system possesses what we have called the third necessary quality, since, when defined in this measure, the unit current of electricity, in passing through a conductor of unit resistance, does a unit of work or its equivalent in a unit of time*.

The entire connexion between the various units of measurement in this system may be summed up as follows.

A battery or rheomotor of unit electromotive force will generate a current of unit strength in a circuit of unit resistance, and in the unit of time will convey a unit quantity of electricity through this circuit, and do a unit of work or its equivalent.

An infinite number of systems might fulfil the above conditions, which leave the absolute magnitude of the units undetermined.

Weber has proposed to fix the series in various ways, of which two only need be mentioned here—first by reference to the force exerted by the current on the pole of a magnet, and secondly by the attraction which equal quantities of electricities exert on one another when placed at the unit distance.

In the first or electro-magnetic system, the unit current is that of which the unit length at a unit distance exerts a unit of force on the unit magnetic pole, the definition of which is dependent on the units of mass, time, and length alone. In the second or electro-static system, the series of units is fixed by the unit of quantity, which Weber defines as that quantity which attracts another equal quantity at the unit distance with the unit force.

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* *Vide* "Application of Electrical Effect to the Measurement of Electromotive Force," Phil. Mag. 1851.

Starting from these two distinct definitions, Weber, by the relations defined above, has framed two distinct systems of electrical measurement, and has determined the ratio between the units of the two systems—a matter of great importance in many researches; but the electro-magnetic system is more convenient than the other for dynamic measurements, in which currents, resistances, &c., are chiefly determined from observations conducted with the aid of magnets.

As an illustration of this convenience, we may mention that the common tangent galvanometer affords a ready means of determining the value in electro-magnetic units of any current γ in function of the horizontal component of the earth's magnetism H, the radius of the coil R, its length L, and the deflexion δ.

$$\gamma = \text{tang. } \delta \, \frac{R^2 H}{L}.$$

In this Report, wherever Professor Weber's, or Thomson's, or the absolute system is spoken of, the electro-magnetic system only is to be understood as referred to. The immense value of a coherent system, such as is here described, can only be appreciated by those who seek after quantitative as distinguished from merely qualitative results. The following elementary examples will illustrate the practical application of the system.

It is well known that the passage of a current through a metal conductor heats that conductor; and if we wish to know how much a given conductor will be heated by a given current in a given time, we have only to multiply the time into the resistance and the square of the current, and divide the product by the mechanical equivalent of the thermal unit. The quotient will express the quantity of heat developed, from which the rise of temperature can be determined with a knowledge of the mass and specific heat of the conductor.

Again, let it be required to find how much zinc must necessarily be consumed in a Daniell's cell or battery to maintain a given current through a given resistance. The heat developed by the consumption of a unit of zinc in a Daniell's battery has been determined by Dr. Joule, as also the mechanical equivalent of that heat; and we have only to multiply the square of the current into the resistance, and divide by the mechanical equivalent of that heat, to obtain the quantity of zinc consumed per unit of time.

Again, do we wish to calculate the power which must necessarily be used to generate by a magneto-electric machine a given current of (say) the strength known to be required for a given electric light.

Let the resistance of the circuit be determined, and the power required will be simply obtained by multiplying the resistance into the square of the current.

Again, the formula for deducing the quantity of electricity contained in the charge of a Leyden jar or submarine cable from the throw of a galvanometer needle depends on the relation between the unit expressing the strength of current, the unit of force, and the unit magnet-pole. When these are expressed in the above system, the quantity in electro-magnetic measure is immediately obtained from the ballistic formula. In estimating the value of the various insulators proposed for submarine cables, this measure is of at least equal importance with the measure of the resistance of the conductor and of the insulating sheath; and the unit in which it is to be expressed would be at once settled by the adoption of the general system described.

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These four very simple examples of the use of Weber's and Thomson's system might be multiplied without end, but it is hoped that they will suffice to give some idea of the range and importance of the relations on which it depends to those who may hitherto not have had their attention directed to the dynamical theory.

No doubt, if every unit were arbitrarily chosen, the relations would still exist in nature, and, by a liberal use of coefficients experimentally determined, the answer to all the problems depending on these relations might still be calculated; but the number of these coefficients and the complication resulting from their use would render such an arbitrary choice inexcusable.

A large number of units of resistance have from time to time been proposed, founded simply on some arbitrary length and section or weight of some given material more or less suited for the purpose; but none of these units in any way possessed what we have called the second and third requisite qualities, and could only have been accepted if the unit of resistance had been entirely isolated from all other measurements. We have already shown how far this is from being the case; and the Committee consider that, however suitable mercury or any other material may be for the construction or reproduction of a standard, this furnishes no reason for adopting a foot or a metre length of some arbitrary section or weight of that material.

Nevertheless it was apparent that, although a foot of copper or a metre of mercury might not be very scientific standards, they produced a perfectly definite idea in the minds of even ignorant men, and might possibly, with certain precautions, be both permanent and reproducible, whereas Weber's unit has no material existence, but is rather an abstraction than an entity. In other words, a metre of mercury or some other arbitrary material might possess what we have called the first, fourth, and fifth requisite qualities, to a high degree, although entirely wanting in the second and third. Weber's system, on the contrary, is found to fulfil the second and third conditions, but is defective in the fourth and fifth; for if the absolute or Weber's unit were adopted *without qualification*, the material standard by which a decimal multiple of convenient magnitude might be practically represented would require continual correction as successive determinations made with more and more skill determined the real value of the absolute unit with greater and greater accuracy. Few defects could be more prejudicial than this continual shifting of the standard. This objection would not be avoided even by a determination made with greater accuracy than is expected at present, and was considered fatal to the *unqualified* adoption of the absolute unit as the standard of resistance.

It then became matter for consideration whether the advantages of the arbitrary material standard and those of the absolute system could not be combined, and the following proposal was made and adopted as the most likely to meet every requirement. It was proposed that a material standard should be prepared in such form and materials as should ensure the most absolute permanency; that this standard should approximate as nearly as possible in the present state of science to ten millions of $\frac{\text{metre}}{\text{seconds}}$, but that, instead of being called by that name, it should be known simply as the unit of 1862, or should receive some other simpler name, such as that proposed by Sir Charles Bright and Mr. Latimer Clark in the paper above referred to; that from time to time, as the advance of science renders this possible, the difference between this unit of 1862 and the true ten millions of

$\frac{\text{metre}}{\text{seconds}}$ should be ascertained with increased accuracy, in order that the error resulting from the use of the 1862 unit in dynamical calculations instead of the true absolute unit may be corrected by those who require these corrections, but that the material standard itself shall under no circumstances be altered in substance or definition.

By this plan the first condition is fulfilled; for the absolute magnitude of this standard will differ by only 2 or 3 per cent. from Dr. Siemens's mercury standard.

The second and third conditions will be fulfilled with such accuracy as science at any time will allow.

The fourth condition, of permanency, will be ensured so far as our knowledge of the electrical qualities of matter will permit; and even the fifth condition, referring to the reproduction, is rendered comparatively easy of accomplishment.

There are two reasons for desiring that a standard should be reproducible: first, in order that if the original be lost or destroyed it may be replaced; secondly, in order that men unable to obtain copies of the true standard may approximately produce standards of their own. It is indeed hoped that accurate copies of the proposed material standard will soon be everywhere obtainable, and that a man will no more think of producing his own standard than of deducing his foot rule from a pendulum, or his metre from an arc of the meridian; and it will be one of the duties of the Committee to facilitate the obtaining of such copies, which can be made with a thousandfold greater accuracy than could be ensured by any of the methods of reproduction hitherto proposed.

It is also hoped that no reproduction of the original standard may ever be necessary. Nevertheless great stress has been lately laid upon this quality, and two methods of reproduction have been described by Dr. Werner Siemens and Dr. Matthiessen respectively; the former uses mercury, and the latter an alloy of gold and silver, for the purpose. Both methods seem susceptible of considerable accuracy. The Committee have not yet decided which of the two is preferable; but their merits have been discussed from a chemical point of view in the appended Report C, by Prof. Williamson and Dr. Matthiessen. An interesting letter from Dr. Siemens on the same point will also be found in the Appendix E. This gentleman there advocates the use of a metre of mercury of one square millimetre section at 0° C. as the resistance unit; but his arguments seem really to bear only on the use of mercury in constructing and reproducing the standard, and would apply as well to any length and section as to those which he has chosen.

When the material 1862 standard has once been made, whether of platinum, gold and alloy, or mercury, or otherwise, the exact dimensions of a column of mercury, or of a wire of gold-silver alloy, corresponding to that standard can be ascertained, published, and used where absolutely necessary for the purpose of reproduction.

It should at the same time be well understood that, whether this reproduction does or does not agree with the original standard, the unit is to be that one original material permanent standard, and no other whatever, and also that a certified copy will always be infinitely preferable to any reproduction.

The reproduction by means of a fresh determination of the absolute unit would never be attempted, inasmuch as it would be costly, difficult, and uncertain; but, as already mentioned, the difference between new absolute

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determinations and the material standard should from time to time be observed and published.

The question, whether the material standard should aim at an approximation to the $\frac{\text{metre}}{\text{second}}$ or $\frac{\text{foot}}{\text{second}}$, was much debated. In favour of the latter it was argued that, so long as in England feet and grains were in general use, the $\frac{\text{metre}}{\text{second}}$ would be anomalous, and would entail complicated reductions in dynamical calculations. In favour of the $\frac{\text{metre}}{\text{second}}$ it was argued that, when new standards were to be established, those should be chosen which might be generally adopted, and that the metre is gaining universal acceptance. Moreover the close accordance between Dr. Siemens's unit and the decimal multiple of the $\frac{\text{metre}}{\text{second}}$ weighed in favour of this unit; so that the question was decided in favour of the metrical system.

In order to carry out the above views, two points of essential importance had to be determined. First, the degree of accuracy with which the material standard could at present be made to correspond with the $\frac{\text{metre}}{\text{second}}$; and secondly, the degree of permanency which could be ensured in the material standard when made.

The Committee are, unfortunately, not able yet to form any definite opinion upon either of these points.

Resistance-coils, prepared by Professor W. Thomson, have been sent to Professor Weber; and he has, with great kindness, determined their resistance in electro-magnetic units as accurately as he could. It is probable that his determinations are very accurate; nevertheless the Committee did not feel that they would be justified in issuing standards based on these determinations alone. In a matter of this importance, the results of no one man could be accepted without a check. Professor Weber had made some similar determinations with less care some years since, but, unfortunately, he has not published the difference, if any, between the results of the two determinations. Indirect comparisons between the two determinations show a great discrepancy, amounting perhaps to 7 per cent.; but it is only fair to say that this error may have been due to some error in other steps of the comparison, and not to Professor Weber's determination. Meanwhile, it was hoped that a check on Weber's last result would by this time have been obtained by an independent method due to Professor Thomson. Unfortunately, that gentleman and Mr. Fleeming Jenkin, who was requested to assist him, have hitherto been unable to complete their experiments, owing chiefly to their occupation as jurors at the International Exhibition. The apparatus is, however, now nearly complete, and it is hoped will before Christmas give the required determinations.

If Professor Weber's results accord within one per cent. with these new determinations, it is proposed that provisional standards shall be made of German-silver wire in the usual way, and that they should be at once issued to all interested in the subject, without waiting for the construction of the final material standard.

The construction of this standard may possibly be delayed for some considerable time by the laborious experiments which remain to be made on the absolute permanency of various forms and materials. An opinion is very prevalent that the electrical resistances of wires of some, if not all, metals are far from permanent; and since these resistances are well known to vary as the wires are more or less annealed, it is quite conceivable that even the ordinary changes of temperature, or the passage of the electric current, may cause such alterations in the molecular condition of the wire as would alter its resistance. This point is treated at some length in the two Reports, B and C, appended, by Professor Williamson and Dr. Matthiessen. The experiments hitherto made have not extended over a sufficient time to establish any very positive results; but, so far as can be judged at present, some, though not all, wires do appear to vary in conducting power.

Mercury would be free from the objection that its molecular condition might change; but, on the other hand, it appears from Report C that the mercury itself would require to be continually changed, and that consequently, even if the tube containing it remained unaltered (a condition which could not be absolutely ensured), the standards measured at various times would not really be the same standard. A possibility at least of error would thus occur at each determination, and certainly no two successive determinations would absolutely agree. If, therefore, wires can be found which *are* permanent, they would be preferred to mercury, although, as already said, no conclusion has been come to on this point.

Some further explanation will now be given of the resolutions passed from time to time by the Committee, and appended to this Report.

Dr. Matthiessen was requested to make experiments with the view of determining an alloy with a minimum variation of resistance due to change of temperature. The object of this research was to find an alloy of which resistance-coils could be made requiring little or no correction for temperature during a series of observations. A preliminary Report on this subject is appended (A), in which the curious results of Dr. Matthiessen's experiments on alloys are alluded to, and, in particular, the following fact connected with the resistance of alloys of two metals is pointed out.

Let us conceive two wires of the two pure metals of equal length, and containing respectively the relative weights of those two metals to be used in the alloy. Let us further conceive these two wires connected side by side, or, as we might say, in multiple arc. Then let the difference be observed in the resistance of this multiple arc when at zero and 100° Cent. This difference will be found almost exactly equal in all cases to the difference which will be observed in the resistance of a wire drawn from the alloy formed of those two metal wires at zero and 100°, although the actual resistance at both temperatures will in most cases be very much greater than that of the hypothetical multiple arc.

In order to obtain a minimum percentage of variation with a change of temperature, it was consequently only necessary to make experiments on those alloys which offer a very high resistance as compared with the mean resistance of their components. The results of a few experiments are given in the Report, but these are only the first of a long series to be undertaken. Hitherto an alloy of platinum and silver is the only one of which the conducting power and variation with temperature are less than that of German silver.

Professor W. Thomson and Dr. Matthiessen were requested to examine the electrical permanency of metals and alloys. A preliminary Report on the subject by Dr. Matthiessen is appended (B), in which he shows that, after four months, one copper and two silver hard-drawn wires have altered, becoming more like annealed wires, but that no decided change has yet been detected in the great majority of the wires.

Several eminent practical electricians were requested to advise the Committee as to the form of coil they considered most suitable for a material standard, and also to furnish a sample coil such as they could recommend. Sir Charles Bright informed the Committee that he was ready to comply with the request. The point is one of considerable importance, respecting which it was thought that practical men might give much valuable information. Coils of wire may be injured by damp, acids, oxidation, stretching and other mechanical alterations. They may be defective from imperfect or uncertain insulation; and they may be inconveniently arranged, so that they do not readily take the temperature of the surrounding medium, or cannot be safely immersed in water- or oil-baths, as is frequently desirable. No definite conclusion as to the form of coil to be recommended, even for copies, has been arrived at.

It was resolved "That the following gentlemen should be informed of the appointment of the present Committee, and should be requested to furnish suggestions in furtherance of its object:—

Professor Edlund (Upsala).
Professor T. Fechner (Leipsic).
Dr. Henry (Washington).
Professor Jacobi (St. Petersburg).
Professor G. Kirchhoff (Heidelberg).
Professor C. Matteucci (Turin).
Professor Neumann (Königsberg).
Professor J. C. Poggendorff (Berlin).
M. Pouillet (Paris).
Werner Siemens, Ph.D. (Berlin).
Professor W. E. Weber (Göttingen)."

A letter, appended to this Report, was consequently addressed to each of these gentlemen. Answers have been received from Professor Kirchhoff and Dr. Siemens, which will be found in the Appendix. The resolution arrived at by the Committee to construct a material standard will entirely meet Professor Kirchhoff's views. The Committee have been unable entirely to adopt Dr. Siemens's suggestions; but his statements as to the accuracy with which a standard can be reproduced and preserved by mercury will form the subject of further special investigation, and the Committee will be most happy to take advantage of his kind offers of assistance.

A letter was also received from Sir Charles Bright, containing an ingenious method of maintaining a constant tension or difference of potentials. This point will probably come before the Committee at a later period, when Sir Charles Bright's suggestion will not be lost sight of.

The Committee also received on the 29th of Sept., after the present Report had been drawn up, a letter from Dr. Esselbach, a well-known electrician, who had charge of the electrical tests of the Malta and Alexandria Cable during its submergence. In this letter Dr. Esselbach arrives at substantially the same conclusions as those recommended by the Committee. Thus, his first conclusion is "to adopt Weber's absolute unit substantially, and to derive from it, by the multiple 10^{10}, the practical unit." This practical unit is precisely that recommended by your Committee. Dr. Esselbach uses the multiple 10^{10}, starting from the $\frac{\text{millimetre}}{\text{second}}$, where your Committee recommend the multiple 10^{7}, starting from the $\frac{\text{metre}}{\text{second}}$: the result is the same.

Dr. Esselbach's next conclusion is also of great practical value. He points out that the electro-magnetic unit of electromotive force, also multiplied by 10^{10}, differs extremely little from the common Daniell's cell, and that, without doubt, by proper care such a cell could be constructed as would form a practical unit of electromotive force. This suggestion has the approval of

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the Committee. Dr. Esselbach next points out that the unit of resistance which he proposes differs very little from Dr. Siemens's mercury unit, which he, like your Committee, considers a great advantage; and the difference is, indeed, less than he supposes. He also proposes to use Weber's absolute unit for the unit of current—a suggestion entirely in accordance with the foregoing Report; and he further points out that this current will be of convenient magnitude for practical purposes. He next approves of the suggestions of Sir Charles Bright and Mr. Latimer Clark with reference to nomenclature and terminology. In the body of his letter he gives some valuable data with reference to the unit of quantity, which he defines in the same manner as your Committee. This result will be analysed in the Report which Professor W. Thomson and Mr. Fleeming Jenkin will make on the fresh determination of the absolute unit of resistance.

The Committee attach high importance to this communication, showing as it does that a practical electrician had arrived at many of the very same conclusions as the Committee, quite independently and without consultation with any of the members. Dr. Esselbach has omitted to point out, what he no doubt was well aware of, that, if, as he suggests, two equal multiples of the absolute units of resistance and electromotive force are adopted, the practical unit of electromotive force, or Daniell's cell, will, in a circuit of the practical unit of resistance, produce the unit current.

Mr. Fleeming Jenkin was requested to furnish an historical summary of the various standards of resistance, but he has been unable to complete his Report in time for the present meeting.

Professor Williamson and Dr. Matthiessen were requested to put together the facts regarding the composition of the various materials hitherto used for standards of resistance, and the physical changes they were likely to undergo. Wires of pure solid metals, columns of mercury, and wires of alloys have been used for the purpose. The Report of the above gentlemen is appended (C). In it they arrive at the following conclusions:—

First, with reference to pure metals in a solid state, they consider that the preparation of those metals in a state of sufficient purity to ensure a constant specific resistance is exceedingly difficult, as is proved by the great discrepancy in the relative conducting powers obtained by different observers. Electrotype copper is excepted from this remark. They also point out that the influence of annealing on the conducting powers of pure solid metals is very great, and would render their use for the purpose of reproducing a standard very objectionable, inasmuch as it is impossible to ensure that any two wires shall be equally hard or soft. They observe that errors of the same kind might be caused by unseen cavities in the wires, and give examples of the actual occurrence of these cavities. They point out another objection to the use of pure solid metals as standards, in the fact that their resistance varies rapidly with a change of temperature, so that slight errors in a thermometer or its reading would materially affect the results of an experiment.

Secondly, with reference to mercury, they show that it is comparatively easily purified, varies little in resistance with a change of temperature, and can undergo no change analogous to that caused by annealing; but that, on the other hand, measurements of its conducting power by different observers vary much, that the tube used cannot be kept full of mercury for any length of time, as it would become impure by partial amalgamation with the terminals, and that consequently each time a mercury standard is used it has, practically, to be remade. The accuracy with which *different* observers can reproduce mercury standards has not been determined.

Thirdly, with reference to alloys, they say that there is better evidence of the independent and accurate reproduction of a standard by a gold-silver alloy of certain proportions than by a pure solid metal or by mercury. They point out that annealing and changes of temperature have far less effect on alloys than on pure metals, and that consequently any want of homogeneity or any error in observing the temperature during an experiment is, with alloys, of little consequence, but that, on the other hand, the existence of cavities must be admitted as possible in all solid wires. They are of opinion that the permanence of jewellery affords strong ground for believing that a gold-silver alloy will be quite as permanent as any solid pure metal; and in the course of the Report they point out some curious facts showing that a great change in the molecular condition of some pure metals and alloys may occur without any proportional change in their conducting powers.

Finally, they recommend that practical experiments should be made independently by several gentlemen to determine whether mercury or the gold-silver alloy be really the better means of reproducing a standard.

The main resolution arrived at by the Committee, viz. that a material standard shall be adopted which at the temperature of 17° Cent. shall approximate to $10^7 \frac{\text{metre}}{\text{seconds}}$, as far as present data allow, has been already fully explained. It was not arrived at until after several meetings had been held and the merits of the various proposals fully discussed.

This resolution was passed (unanimously) at a meeting when five out of the six members of the Committee were present.

It was at the same time resolved that provisional copies should be distributed at the present Meeting; but the circumstances have been already explained which have prevented this resolution from being carried into effect.

It was thought desirable that an apparatus should be designed which could be recommended by the Committee for use in copying and multiplying the units to be issued, since it is certain that some of the glaring discrepancies in coils intended to agree must have been due to defective modes of adjustment. Mr. Fleeming Jenkin has consequently designed an apparatus for the purpose, of which a description is appended. Messrs. Elliott Brothers have kindly constructed a couple of these instruments, which were seen in action, at the Meeting of the Association, by members interested in this subject.

The present Report was drawn up by Mr. Jenkin, and adopted at a meeting of the Committee on the 30th of September.

Appendix to Report on Standards of Electrical Resistance.

A. On the variation of the electrical resistance of alloys due to change of temperature, by Dr. Matthiessen, F.R.S.

B. On the electrical permanency of metals and alloys, by Dr. Matthiessen, F.R.S.

C. On the reproduction of electrical standards by chemical means, by Professor Williamson, F.R.S., and Dr. Matthiessen, F.R.S.

D. Professor Kirchhoff's letter.

E. Dr. Siemens's letter.

F. Dr. Esselbach's letter.

G. Circular addressed to foreign men of science.

H. Description of apparatus for copying and multiplying the units of resistance.

APPENDIX A.—*On the Variation of the Electrical Resistance of Alloys due to Change of Temperature.* *By* Dr. MATTHIESSEN, *F.R.S.*

It has been shown* that the influence of temperature on the electric conducting power of the metals amounts to 29·3 per cent. on their conducting power between 0° and 100° C.: an exception to this law has been found in iron†, the conducting power of which decreases between those limits 38·2 per cent. It was, therefore, useless to try any of the other pure metals, as they would, in all probability, have decreased by the same amount, as well as from the fact that the metals which would have suited the purpose had already been tried. I therefore turned my attention to the alloys, and, in conjunction with Dr. C. Vogt, have made a long series of experiments respecting the influence of temperature on their electric conducting power. After having determined the conducting power of a few of them at different temperatures, together with the help of the few experiments which have already been made by different observers, it became obvious that the percentage decrement in their conducting power stands in some relation to the fact that, when a solid metal is alloyed with another (with the exception of lead, tin, zinc, and cadmium amongst each other), a lower conducting power is observed than the mean of that of the components ‡. The law which we found to regulate this property was with most alloys the following, viz.:—

"*The percentage decrement between* 0° *and* 100° *in the conducting power of an alloy in a solid state stands in the same ratio to the mean percentage decrement of the components between* 0° *and* 100° *as the conducting power of the alloy at* 100° *does to the mean conducting power of the components at* 100°;" or, in other words, "*the absolute difference in the observed resistance between* 0° *and* 100° *of an alloy is equal to the absolute difference between the means of the resistance of the component metals between* 0° *and* 100°."

For example, the conducting power of the hard-drawn gold-silver alloy was found equal to 15·03 at 0° (taking silver equal 100° at 0°), and decreases 6·49 per cent. between 0° and 100°. The mean decrement of the components between 0° and 100° being 29·3 per cent., the conducting power of the alloy is 14·05 at 100°, and that of the mean of the components is 62·58 at 100°. If we now calculate the percentage decrement in the conducting power of the alloy between 0° and 100° from the above data, we find it equal to 6·58 per cent., and by experiments it was found equal to 6·49 per cent. Or, taking the resistance of silver at 0°=100, and that of gold at 0°=128·3, we find the resistance of the alloy at 0°=665·3, and at 100°=711·7, and that calculated from a mean of the volumes of its components at 0°=113·2, and at 100°=159·8; therefore the absolute difference between the observed resistance at 0° and 100° is 46·4, and that between the calculated at 0° and 100°=46·8.

Knowing already, from my experiments on the electric conducting power of alloys§, that when two metals are alloyed together in any proportion, if the alloy is merely a solution of the two metals in one another, its conducting power may be approximatively foretold, and that, from the above law, it is necessary that if the conducting power of an alloy should vary between the limits of 0° and 100° to a minimum extent, the alloy itself must have a minimum conducting power as compared with that calculated from its components,—I at once foresaw that it would be useless, as was afterwards proved by the research made in conjunction with Dr. Vogt, to make any experiments with the two metal-alloys, which may be looked upon as a solution of one metal in the other, as no practical alloy would be found which would vary in its conducting power between 0° and 100° to a small extent. It must also be borne in mind that the alloy sought for must be a ductile one, capable of being drawn into wire, not too soft, as would easily be damaged by covering and winding, easily produced, and cheap in price. Bearing this in mind, we turned our attention to some three metal-alloys, thinking that we had some chance there of obtaining a good result; for it is well known that the conducting power of German-silver wire varies in such a slight extent between 0° and 100°.

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* Phil. Trans. 1862, pt. 1.

† Matthiessen and Vogt, unpublished researches.

‡ Assuming that the conducting-power or resistance of an alloy is equal to that of parallel wires of the components forming it.

§ Phil. Trans. 1860, p. 161.

It also appeared worth while to experiment with some of those alloys which may perhaps be considered chemical combinations, or to contain such, as, for instance, platinum and silver; and, on account of their other physical properties, the platinum-iridium alloys were also experimented with.

In the following Table I give the results obtained in conjunction with Dr. Vogt. The unit here taken for comparison is that of a hard-drawn silver wire at 0°. The normal wires were made of German silver, and in order to obtain their values in terms of hard-drawn silver, they were compared with the gold-silver alloy. In these experiments it was thought better first to use those pure metals which are easily obtained, so as to learn something regarding the manner in which the three metal-alloys behave, and then try some alloys made of the cheaper commercial metals. As will be seen by the Table, only the first part has been as yet carried out.

TABLE.

(With each series, the formula deduced from the observations for the correction of the conducting power of the alloy for temperature is given, when λ is equal to the conducting power at the temperature t C.)

Composition of alloy.	Weight.
(1) Gold	58·3
Copper	26·5
Silver	15·2

Made from pure metals.
Hard-drawn.

Length 532 mm.; diameter 0·625 mm.

T.	Conducting power. Found.
9·0	11·956
53·5	11·674
100·	11·438

$$\lambda = 12{\cdot}017 - 0{\cdot}0069033t + 0{\cdot}0000111t^2.$$

This alloy was taken as Karmarsch states it is the hardest and most elastic of all the gold-silver-copper alloys.

(2) Gold	66·5
Silver	18·1
Copper	15·4

Made of pure metals.
Hard-drawn.

Length 341·5 mm.; diameter 0·618 mm.

T.	Conducting power. Found.
10·95	10·5637
33·52	10·4341
55·15	10·3130
78·35	10·1846
97·52	10·0852

$$\lambda = 10{\cdot}6220 - 0{\cdot}0056248t + 0{\cdot}0000009863t^2.$$

This alloy was tried as it corresponded to equal volumes of gold-copper and gold-silver, and these again correspond to an alloy possessing the lowest conducting power of any of those made of gold-copper or gold-silver.

Composition of alloy.		Weight.
(3)	Copper	78·3
	Silver	14·3
	Gold	7·4

Made from pure metals.
Hard-drawn.

Length 764 mm.; diameter 0·553 mm.

T.	Conducting power. Found.
11·0	45·591
55·5	40·333
100·	37·560

$$\lambda=44{\cdot}472-0{\cdot}081525t+0{\cdot}0003240t^2.$$

This alloy was taken to see the effect such a combination would have.

(4)	Platinum	66·6
	Iridium	33·4

Commercial alloy.
Hard-drawn.

Length 244 mm.; diameter 0·682 mm.

T.	Conducting power. Found.
12·0	4·506
56·0	4·384
100·0	4·271

$$\lambda=4{\cdot}541-0{\cdot}0029307t+0{\cdot}000002724t^2.$$

This alloy was tried as it possesses very great elasticity and does not become softer on annealing. On account of these properties, as well as its permanency in air (not oxidizing on its surface), it would serve exceedingly well for making springs and contacts for electric and telegraphic apparatus.

(5)	Silver	95·0
	Platinum	5·0

Made from pure silver and commercially pure platinum.
Hard-drawn.

Length 381·5 mm.; diameter 0·451 mm.

T.	Conducting power. Found.
12·0	31·173
56·0	29·550
100·0	28·068

$$\lambda=31{\cdot}640-0{\cdot}039363t+0{\cdot}00003642t^2.$$

This and the following two alloys were taken as they probably contain chemical combinations.

(6)	Silver	90·2
	Platinum	9·8

The metals employed were the same as in No. 5.
Hard-drawn.

Length 708 mm.; diameter 0·26 mm.

T.	Conducting power. Found.
9·0	17·920
54·5	17·319
100·0	16·767

$$\lambda=18{\cdot}045-0{\cdot}013960t+0{\cdot}00001183t^2.$$

(7)	Silver	66·6
	Platinum	33·4

Commercial alloy.
Hard-drawn.

Length 169 mm.; diameter 0·408 mm.

T.	Conducting power. Found.
8·270	6·6850
54·00	6·5826
99·90	6·4987

$$\lambda=6{\cdot}7032-0{\cdot}0022167t+0{\cdot}000001394t^2.$$

In the following Table I have given the results in such a manner that they may be easily compared.

TABLE.

	Conducting power at 0°.	Percentage variation in conducting power between 0° and 100°.
Pure iron	....	38·2
Other pure metals in a solid state	....	29·3
Alloy 3	44·5	15·5
„ 5	31·6	11·3
„ 6	18·0	7·1
„ Gold-silver*	15·0	6·5
„ 4	4·5	5·9
„ 2	10·6	5·2
„ 1	12·0	4·8
„ German silver†	7·8	4·4
„ 7	6·7	3·1

The method and apparatus employed for the above determinations, together with the precautions taken to ensure correct results, have already been described‡. We have made only three observations between 0° and 100°, for it was found that they gave almost exactly the same formulæ for the correction of the conducting power for temperature as if we had taken seven or more observations between 0° and 100°. Each of the above values for the conducting power, at those temperatures, is the mean of three or more observations. It was easy to obtain the desired temperatures as a mean of several observations, after very little practice. I have no doubt that, in the course of our experiments, we shall be able to find an alloy, the conducting power of which will decrease between 0° and 100° even less than that of silver-platinum. The experiments are being continued, and I hope, before the next meeting of the Association, to be able to lay before you results which will throw more light on the subject, as well as to propose an alloy with a minimum variation in its conducting power due to change of temperature, which may be made commercially in a cheap manner of the common commercial metals, and possessing those properties which are essential that it should have.

APPENDIX B.—*On the Electrical Permanency of Metals and Alloys.* *By* DR. MATTHIESSEN, *F.R.S.*

Having, in conjunction with Prof. Thomson, been requested by your Committee to make some experiments on this subject, we thought it advisable for one of us to undertake some preliminary experiments in which all possible disturbing causes were isolated. The chief of these are, oxidation by the oxygen of the air, as well as by acids produced by the oxidation of the oil or grease with which a wire is almost always covered when drawn, as the holes in the draw-plates are generally oiled or greased; stretching during the process of covering and winding; and after being wound on the bobbin, elongation by expansion or contraction, owing to variations of temperature, &c. These, I think, have been obviated in the following manner:—The wires were carefully wound round a glass tube in order to bring them into a smaller compass, and after taking them off, they were placed inside wide glass tubes, and soldered to two thick copper wires, these having been previously passed through corks which fitted into the ends of the glass tube; through each of the corks a small glass tube passed, drawn out in the middle to enable it to be drawn off easily, and sealed hermetically by a lamp. The wire being soldered to the thick copper connectors, and the corks fitted into the tube, dry carbonic-acid gas was led through it for the space of about six hours, for the purpose of drying it perfectly, as well as of displacing the air contained in it; after which the small glass tubes were melted off at the points, when they have been previously drawn out. Tin caps, filled with melted marine glue, were then fitted over the corks and the ends of the tube, to prevent diffusion of the carbonic acid and air through the corks. The whole of the tin caps outside, as well as those parts of the copper-wire connectors which dipped in water of the bath in which they were placed whilst being tested, were covered with a thick coating of marine glue.

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* Phil. Mag. Feb. 1861. † Phil. Trans. 1862, pt. 1. ‡ Ibid.

The wires experimented with were as follows:—

1. Silver: hard-drawn	Cut from the same piece; pure.
2. Silver: annealed	
3. Silver: hard-drawn	Cut from the same piece, but different from 1 and 2; pure.
4. Silver: annealed	
5. Copper: hard-drawn	Cut from the same piece; pure.
6. Copper: annealed..........	
7. Copper: hard-drawn	Cut from the same piece, but different from 5 and 6; pure.
8. Copper: annealed..........	
9. Gold: hard-drawn	Cut from the same piece; pure.
10. Gold: annealed............	
11. Gold: hard-drawn	Cut from the same piece, but different from 9 and 10; pure.
12. Gold: annealed............	
13. Platinum: hard-drawn	Cut from the same piece; commercial.
14. Platinum: hard-drawn	
15. Gold-silver alloy: hard-drawn	Cut from same piece. Made by Messrs. Johnson and Matthews.
16. Gold-silver alloy: hard-drawn	
17. German silver: annealed	Cut from the same piece. No. 19 arranged with longer connectors, and used as normal wire with which the rest were compared.
18. German silver: annealed	
19. German silver: annealed	

The reason why duplicates were made in each case was that, in case any of them should by any cause get damaged, the experiments might be continued with the duplicate. When being tested, they were placed in a large bath containing from 40 to 50 litres of water. By testing the wires at 20° it was found easy to keep that temperature in the bath, during the experiments, to 0·1° or 0·2°.

Up to the present time, that is to say, four months since they were first tested, the conducting power of the wires 1, 3, and 5 has altered, owing to becoming, in all probability, partially annealed. Wire 8 has also altered materially, having decreased in conducting power 3·5 per cent.: this decrement may be possibly due to bad soldering. The differences found with the other wires are so very small, that it is impossible to say whether they have altered or not; for 0·1° or 0·2° will account for them. It was, therefore, thought better to wait for another two or four months before giving an opinion as to whether they alter or not; for as the wires are in tubes and only surrounded by carbonic acid, we can never be absolutely sure that the wire has exactly the same temperature as the bath, more especially when it is considered that each time the connexion with the battery is made the wire becomes somewhat heated.

If, two or four months hence, they still show no difference in their conducting powers, it is proposed to expose the one set to variations of tempera-

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ture such as may occur (for instance, from 0° to 40°), and then, should no change occur in their conducting powers, to lead a weak current through them, say, for a month; for it has been asserted that a current passing through wire causes a permanent change in its conducting power.

If after these experiments the conducting power of the wires remains unaltered, the different forms of resistance-coils, made from those wires, which have shown themselves permanent will then be tested in order to prove which is the best form of coil for the British Association unit.

APPENDIX C.—*On the Reproduction of Electrical Standards by Chemical Means. By* Professor WILLIAMSON, *F.R.S., and* Dr. MATTHIESSEN, *F.R.S.*

In the following Report we have discussed, more especially from a chemical point of view, the relative merits of the different propositions which have been made to reproduce standards of electric resistance, and have treated them under three heads:—

I. *Those reproduced by a given length and section or weight, at a given temperature, of a pure metal in a solid state.*
II. *Those reproduced by a given length and section or weight, at a given temperature, of a pure metal in a liquid state.*
III. *Those reproduced by a given length and section or weight, at a given temperature, of an alloy.*

The points on which we shall speak will be—

1. *On their preparation in a state of purity.*
2. *On their homogeneity and their molecular condition.*
3. *On the effect of annealing on their conducting power.*
4. *On the influence of temperature on their conducting power.*

I. *Those reproduced by a given length and section or weight, at a given temperature, of a pure metal in a solid state.*

As type of this class we have chosen copper, for it has been more extensively used as unit of electric resistance, both by scientific as well as by practical men, than any other metal or alloy; but what we are about to say regarding copper will hold good in almost every case for all pure metals in a solid state.

1. *On its preparation in a state of purity.*—As traces of foreign metals materially affect the conducting power of most pure metals, it is of the utmost importance that those used for the reproduction of units of electric resistance should be absolutely chemically pure. The difficulty in obtaining absolutely pure metals even by chemists is very great. Thus, for instance, Becquerel* found the conducting power of pure gold at 0° equal to 68·9, compared with that of pure silver at 0° equal to 100; whereas, under the same circumstance, Matthiessen and von Bose† found it equal to 77·9,—showing a difference of about 12 per cent. in the values observed for the conducting power of gold, prepared pure by different chemists. This difference may be due to the silver not being pure, or to all of them being more or less pure. Now when we consider that these standards are required by electricians and other physicists who have little or no acquaintance with chemical manipulation, and that the cost of the preparation of absolutely pure metals by scientific chemists would be very expensive on account of the time and trouble they require, we think that this fact alone constitutes a very serious drawback to their use

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* Ann. de Chim. et de Phys. (1846) t. xvii. p. 242.

† Phil. Trans. 1862, pt. 1.

as a means for the reproduction of standards of electric resistance. From the experience which one of us has had on this subject, it is more than probable that if pure metals be prepared by different chemists in the ordinary way of business, variations in their conducting power would be found equal to several per cent. Thus, copper supplied as *pure* by a well-known assayer had a conducting power equal to 92, whereas pure copper conducts at the same temperature 100[*]. Again, the *pure* gold of the assayer conducts only 65·5, whereas pure gold at the same temperature would have a conducting power equal to 73[†]. In order to show that the conducting power of commercial metals varies to a great extent, we give in the following Table (X.) the values found for that of the different coppers of commerce; and it will be evident from it, that to take a given length and weight or section of a commercial metal as unit, as has often been done, is very wrong, and can only lead to great discrepancies between the results of different observers.

TABLE X.[‡]

(All the wires were annealed.)

	Conducting power.
Pure copper	100·0 at 15·5
Lake Superior native, not fused	98·8 at 15·5
Ditto, fused, as it comes in commerce	92·6 at 15·0
Burra Burra	88·7 at 14·0
Best selected	81·3 at 14·2
Bright copper wire	72·2 at 15·7
Tough copper	71·0 at 17·3
Demidoff	59·3 at 12·7
Rio Tinto	14·2 at 14·8

Similar variations will be found with most other metals, and we shall give examples of these further on.

2. *On its homogeneity and its molecular condition.*—It is well known that the wires of some metals require much more care in drawing than in others: thus, copper and silver, if not annealed often enough during the process of drawing, will often become quite brittle, and break off short when bent. Now, if the fracture be closely observed, it will be seen that the wire is hollow; in fact, wherever it is broken, cavities will be found, and sometimes of a millimetre or two in length; so that such a wire may almost be regarded as a tube with a very fine bore. The reason of this is simply that in not annealing the wire often enough, the internal part of it becomes hard and brittle, whilst the outside remains annealed, from the heat evolved by its passage through the holes of the draw-plates; after a time, however, the inside, being very brittle, will give way, whilst the outside is still strong enough to bear the force used in drawing it through the draw-plates. These places in the wires are easily discovered on drawing the wire finer; for then at these points the wire slightly collapses, owing to the quicker elongation of the weak points by the force used in drawing. Silver and copper are the only metals which have been experimented with in this manner; we are therefore unable to say whether it may occur with the other metals. However, although no such wires could be used for experiments, yet what has been shown possible to occur to such a marked extent when purposely trying to obtain such results, may occur

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[*] Proceedings of the Royal Society, vol. xi. p. 126.

[†] Phil. Trans. 1860, p. 176.

[‡] Report of the Government Submarine Cable Committee, p. 335.

to some slight extent, especially when great care is not used, and when the wires are drawn by different persons. This may explain why, with some metals and alloys of the same preparation, conducting powers are often obtained which vary several per cent. For instance, W. Thomson* found the conducting power of several alloys of copper which he had had made and tested to alter considerably on being drawn finer; some of them were faulty from the cause we have just mentioned, and, on their being drawn finer, these places showed themselves, and were then cut away.

It has also been shown† that when copper wire is heated to 100° for several days, a permanent alteration takes place in its conducting power: thus, with the first wire experimented on, it increased almost to the same extent as if it had been annealed. With the second wire the increment was not nearly so large as with the first, and with the third it hardly altered at all. That this is not due to one or the other of the wires being faulty in the just-mentioned manner is proved,

1st, By the close agreement in the conducting powers.

2nd, By the close agreement between the differences in the values found for the conducting powers of the hard-drawn and annealed wires. They were—

	1st wire at 0°.	2nd wire at 0°.	3rd wire at 0°.
Hard-drawn	99·5	100·0	100·3
Annealed	101·8	102·1	102·2

The values given for the hard-drawn wires are those which were observed before the wire was heated at all.

3rd, That the same occurs with pressed wires: thus, with bismuth it was found that the pieces of the same wire behaved differently; wire 1 showing, after 1 day's heating to 100°, an increment in the conducting power of 16 per cent., whereas wire 2 increased, although a piece from the same length of wire, 9 per cent.

Again, take the case of tellurium, and taking the conducting power of each bar at first equal to 100, we find that the conducting power of bar 1 had decreased after 13 days' heating to 4, where it then remained constant, that of bar 2 after 32 days became constant at 19, and that of bar 3 after 33 days at 6.

The cause of these marked changes in the conducting power must therefore be looked for in the molecular arrangement of the wires or bars employed. In the case of copper, they may be, and probably are, due to the partial annealing of the wires; for we find that wire 1, although the conducting power increased after having been kept at 100° for several days almost to the same extent as if it had been annealed, yet, on annealing it, it only gained as follows (the results obtained with wires 2 and 3 are added):—

	1st wire at 0°.	2nd wire at 0°.	3rd wire at 0°.
Hard-drawn	99·5	100·0	100·3
After being kept several days at 100°	101·6	101·6	100·6
After annealing	101·8	102·1	102·2

The above shows that, in all probability, the annealing plays here a part, but not the whole, in the change; for otherwise why do the wires behave differently? This point will be fully discussed in another Report which will be laid before your Committee, and in which it will be shown where the hard-drawn wires become partially annealed, and annealed wires partially hard-drawn, by age.

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* Proceedings of the Royal Society, vol. xi. p. 126.

† Phil. Trans. 1862, pt. 1.

It is a curious fact that a change in the molecular arrangement of the particles of wire of some metals which may be considered homogeneous has very little effect on its electric conducting power. Thus pure cadmium*, which when cold is exceedingly ductile, becomes quite brittle and crystalline at about 80°, and returns again to its ductile condition on cooling, shows no marked change in its conducting power at that temperature; in fact, it behaves as if no such change had taken place. Again, when iron wire is heated in a current of ammonia it becomes perfectly brittle and crystalline, without altering its conducting power to any marked extent.

That a wire which changes its molecular condition in becoming crystalline does not necessarily materially alter in its conducting power, is an important as well as a very interesting point, and has also been proved in the case of German silver.

3. *On the effect of annealing on the conducting power.*—When hard-drawn wires of silver, copper, gold, &c., are heated to redness and cooled slowly, they become much softer, and on testing their conducting powers they will be found to have increased thus:—

	Silver.	Copper.	Gold.	According to
Taking the hard-drawn wire	100·0	100·0	100·0	
The annealed will be	107·0	102·6	101·6	Becquerel†.
Ditto	109·0	102·3	102·0	Matthiessen and von Bose‡.
Ditto	110·0	106·0	—	Siemens§.

Now there is a certain difficulty in drawing a wire which is hard-drawn; and if annealed wires be used for the reproduction of standards, the molecular condition, or perhaps the process of annealing, has an influence on the increment of the conducting power. Thus, according to Siemens||, the difference in the conducting power between hard-drawn and annealed silver varies between 12·6 and 8 per cent., and that of copper between 6 and —0·5 per cent.; according to Matthiessen and von Bose¶, that of silver varies between 10 and 6 per cent., and that of copper between 2·6 and 2 per cent.

Again, the annealed wires of pure metals are so soft that they would easily get damaged in covering them with silk or winding them on the bobbins, so that in using them the utmost care would have to be employed in order to prevent their getting injured.

4. *On the influence of temperature on the electric conducting power.*—It has been shown that the conducting power of most pure metals decreases, between 0° and 100°, 29·3 per cent.: pure iron has been found to form an exception to this law, its conducting power decreasing between those temperatures 38·2 per cent. If pure metals be therefore used as standards, very accurate thermometers are necessary, as an error of 0·1° in comparing two standards would cause an error in the resistance of about 0·04 per cent. Now there is great difficulty in obtaining normal thermometers; and we must

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[*] Phil. Trans. 1862, pt. 1.

[†] Ann. de Chim. et de Phys. 1846, t. xvii. p. 242.

[‡] Phil. Trans. 1862, pt. 1.

[§] Phil. Mag. Jan. 1861.

[||] Phil. Mag. Jan. 1861.

[¶] Matthiessen and Vogt's unpublished researches.

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bear in mind that supposing the zero-point of the thermometer is correct to-day, we are not at all justified in assuming that it will be so in six months time; so that we ought to redetermine the zero-point of the thermometer before using it for the above purpose. Again, it has been proved that the influence of temperature on the conducting power of wires of the same metal is not always the same*. Thus, for the conducting power of annealed copper wires the following values were found:—

°	No. 1.	No. 3.
0	100·0	100·0
20	92·8	92·4
40	86·3	85·6
60	80·4	79·6
80	75·1	74·4
100	70·5	70·0

showing therefore that if standards of pure metals be used, the influence of temperature on the conducting power of each would have to be ascertained. It must also be borne in mind that it is not at all easy to maintain a standard, even in a bath of oil or water at a given temperature, for any length of time.

II. *Those reproduced by a given length and section or weight of a pure metal in a liquid state.*

The only metal which has been proposed to be used in a liquid state for the reproduction of units of resistance is mercury. We shall only have to speak of its preparation in a state of purity, and on the influence of temperature on its conducting power. For a tube, carefully filled with mercury, will certainly form a homogeneous column, and its molecular condition will always be the same at ordinary temperatures.

On its preparation in a pure state.—Although this metal is one of the most easily purified, yet the use of it as a standard is open to the same objections, although in a less degree, as have been advanced against the use of pure metals in a solid state when speaking of their preparation. We there stated that metals prepared by different chemists conducted differently. Now although the same manipulator may obtain concordant results in purifying metals from different sources, yet that by no means proves that the results of different observers purifying the same metal would show the same concordance. Thus we find that the values obtained by one experimenter† for the resistance of mercury, determined in six different tubes, varied 1·6 per cent. This difference, he says, is not greater than was to be expected. The resistances found were as follows:—

Tubes.	I.	II.	III.	IV.	V.	VI.
Experiment. . .	1016·52	427·28	555·38	217·73	194·70	1142·3
Calculated	1025·54	427·28	555·87	216·01	193·56	1148·9

Again, the values found for the conducting power of different preparations of pure hard-drawn gold, by the same observer ‡, were found equal to

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* Phil. Trans. 1862, part 1.

† Phil. Mag. Jan. 1861. The same experimenter (Dr. Siemens) states, however, in a later paper (Pogg. Ann. cxiii. p. 95), that he is able to reproduce standards of resistance by means of mercury with an accuracy equal to 0·05 per cent., but does not indicate what other precautions he takes (see remarks on the above, Phil. Mag. Sept. 1861).

‡ Phil. Trans. 1862, p. 12.

78·0 at 0°	78·2 at 0°	76·8 at 0°
79·5 at 0°	78·3 at 0°	76·7 at 0°
77·0 at 0°	78·0 at 0°	77·3 at 0°

These values agree together as well as might be expected, considering that 0·01 per cent. impurity would cause these differences. Now the values obtained by different observers vary between the numbers 59 and 78.

If we now take the case of copper, the values found by the same experimenters[*] for different preparations of the pure hard-drawn metal were—

99·9 at 0°	99·4 at 0°	99·8 at 0°
101·0 at 0°	99·4 at 0°	100·3 at 0°
99·8 at 0°	99·9 at 0°	100·0 at 0°
99·9 at 0°		

They were drawn by themselves, and all, with one exception, electrotype copper.

It is well known how differently the so-called *pure* copper conducts when prepared by different experimenters. In the following Table, in order to show these facts more clearly, we have given the conducting powers of the metals, taking that of silver equal 100 at 0°. Silver, copper, gold, and platinum were hard-drawn. All values given, except where the contrary is mentioned, have been reduced to 0°.

	Siemens.	Lenz.	Becquerel.	Matthiessen.
Silver[†]	100	100	100	100
Copper	96·9	73·4	95·3	99·9
Gold	……	58·5	66·9	78·0
Cadmium	……	……	26·3	23·7
Zinc	……	……	25·7	29·0
Tin	……	22·6	15·0	12·3
Iron	……	13·0	13·1	14·4 at 20·4
Lead	……	10·7	8·8	8·3
Platinum	14·2	10·4	8·6	10·5 at 20·7
Mercury	1·72	3·42 at 18·9	1·86	1·65

If now mercury be taken as unit, we find the following values:—

	Siemens.	Lenz.	Becquerel.	Matthiessen.
Silver	58·20	29·24	53·76	60·60
Copper	56·40	21·46	51·23	60·55
Gold	……	17·10	37·04	47·27
Cadmium	……	……	14·14	14·42
Zinc	……	……	13·82	17·70
Tin	……	6·59	8·10	7·45
Iron	……	3·80	7·04	8·72 at 20·4
Lead	……	3·12	4·73	5·03
Platinum	8·25	3·04	4·62	6·36 at 20·7
Mercury	1·00	1·00 at 18·7	1·00	1·00

A glance at the foregoing Tables will suffice to show how badly Lenz's series agrees with the rest when mercury is taken as unit; and, in fact, we obtain more concordant results if, in the above series, we take any other metal as unit. These facts therefore seem to indicate that mercury is not yet proved to be a safe means of reproducing standards of electric resistance.

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[*] Phil. Trans. 1862, p. 9.

[†] This and the following Table have been copied from a paper published in the Phil. Mag. for Sept. 1861.

The influence of temperature on the conducting power of mercury, between 0° and 100°, is, comparatively speaking, small, being only 8·3 per cent., whereas that of the metals in a solid state decreases between those limits 29·3 per cent. This property would, of course, render the use of very accurate thermometers unnecessary; for 1° would only cause a difference in the conducting power of about 0·08 per cent., and therefore 0·1 only 0·008 per cent., so that an error of 1 or 2 tenths of a degree might almost be overlooked.

A fact has just come to our knowledge through Mr. Jenkin. He informs us that, having to make a report on the electric apparatus in the International Exhibition, he tested, amongst other things, several resistance-coils. Now he found two sets of coils made by the same firm, the one exhibited in the Prussian, the other in the English department. Both were said to be multiples of the mercury unit proposed by Siemens*, and their resistances determined by comparing a coil in each set with that of a tube filled with mercury. Taking each set by itself and comparing the coils in it with one another in the proper combination, they were found to be perfect; in fact, the adjustment of them was perfectly accurate. When, however, Mr. Jenkin compared coils of the two sets with each other, instead of being equal, they were found to show a difference of 1·2 per cent.†

III. *On those reproduced by a given length and section or weight, at a given temperature, of an alloy.*

The alloy on which we have to speak is that composed of two parts by weight of gold and one of silver. The reason why this alloy was proposed is that the use of (say) 1 per cent. more or less gold does not materially alter its conducting power.

1. *On its preparation.*—It has been shown that the alloy may be made of commercially pure metals and have the same conducting power as that made from chemically pure ones; for the maximum differences in the conducting power between those made in different parts of the world are not greater than those of a pure metal, either in a solid or liquid state, prepared by the same experimenter. But it may be urged that part of the differences obtained by different observers is due to the different methods employed in determining their conducting powers, and therefore had the conducting power of these alloys being determined by different persons, much greater differences would have been found. In answer to this, we give, in the following Table, the determination of the conducting power of several alloys by Thomson and Matthiessen ‡, independently of one another. The alloys were made by Messrs. Johnson and Matthey.

Alloy.	Thomson.	Matthiessen.
1	100·0	100·05
2	95·8	95·0
3	102·9	102·7
4	100·8	99·1
5	98·1	97·7
6	89·9	92·7
7	80·6	80·06

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* Phil. Mag. Feb. 1861.

† This discrepancy may perhaps be attributed to some inaccuracy in the reproduction of the mercury standard.

‡ Proceedings of the Royal Society, Feb. 1861.

Pure copper.	Thomson.	Matthiessen.
1	107·0	107·2
2	107·5	105·9
3	108·7	106·9
4	107·7	108·1

The differences here, with the exception of alloy 6 and copper 2, may be due to the temperature at which the observations were made not being in both cases the same; for 2 or 3 degrees' difference will account for them. The Table, however, shows that different observers do obtain the same values for the conducting power of the same wires.

The values obtained for the conducting power of the gold-silver alloy, made by different persons, of different gold and silver, are given in the following Table—

Alloy.	Hard-drawn.	Annealed.
1	100·3	100·6
2	100·2	100·7
3	98·8	99·2
4	....	100·2
5	100·4	100·7
6	99·7	99·8
7	100·3	100·8
8	100·1	100·4

which shows, therefore, that the alloy may be prepared in a commercial way, and still have a conducting power which varies less than that of a pure metal prepared at different times by the same experimenter. If we look at the hard-drawn series, we find five out of the seven wires tested agree together exceedingly well, the greatest difference being only 0·3 per cent. These five alloys were made, three in London, by scientific chemists, one in Frankfort-on-the-Maine, and one in Brussels. Those which agree least with the others were made in New York (No. 3) and by a well-known assayer in London (No. 6).

2. *On its homogeneity and its molecular condition.*—If the wires of the alloy made and drawn by different persons were not homogeneous, the values obtained for the conducting power could not have agreed so well together. It has been already mentioned that some of the alloys determined by Thomson, when redrawn, were found to have a different conducting power *.

Alloy.	Conducting power of wire as received from the wire-drawer.	Conducting power after being re-drawn.
1	100·0	100·0
2	100·7	95·8
3	103·9	102·9
4	94·6	100·8
5	96·0	98·1
6	92·0	89·9
7	74·7	86·0
Pure copper.	100·0	98·6

Of course, here again, some of these differences are due to the temperature in each case not being the same; but the differences found with the alloys 2, 4, and 6 were undoubtedly due to faulty wires. It was for this reason that care was taken to have the alloy drawn by different persons, in order to see if this would influence the results obtained with them, as well as to ascertain whether the wires would show the same faults as silver and copper does when not carefully drawn. It has been argued that the molecular condition of all alloys is liable to undergo a change by age, and that, therefore, alloys are not fit to be used as standards. Thus, it is well known that brass and German silver become brittle and crystalline by age, and that the same may occur with the gold-silver alloy; but on looking at the composition of the alloy, it will be found to have nearly the same as that of the gold chains of commerce. Now, we do not know of a single instance where such a chain, even after years of use, becomes brittle or crystalline; so that we think it more than possible that the alloy will not change its molecular condition by age. It must also be remembered that even when German silver becomes brittle, it does not materially alter in its conducting power. The same has already been proved, and mentioned in this Report, to be the case with iron and cadmium.

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* Proceedings of the Royal Society, Feb. 1861.

3. *On the effect of annealing on the conducting power of the alloy.*—When the alloy is heated to redness and cooled slowly, its conducting power was found to have increased only 0·3 per cent.—this value being the mean of eight wires annealed in different ways,—proving, therefore, that if the wires may be only partially hard-drawn, it will make but little difference in the conducting power.

4. *On the influence of temperature on the conducting power of the alloy.*—When wires of this alloy are heated from 0° to 100°, a decrement in the conducting power, amounting to 6·5 per cent., will be found. The same arguments may, therefore, be put forward in favour of the use of the alloy as a standard, as were done in the case of mercury when speaking of this property.

To sum up, therefore, the arguments in favour of and against the use of the three propositions made to reproduce standards of electric resistance, we find in favour of a pure metal in a solid state:—

1. That it appears that all descriptions of electrotype copper, when carefully drawn, have the same conducting power.

Against it:—

1. That their preparation, with the exception of the electrotype copper in a state of purity, is exceedingly difficult; so that independent persons preparing the same metal find, on comparing the conducting powers obtained for them, that they vary several per cent.
2. That the influence of annealing on their conducting powers is so great that differences may occur simply because the wires are partially hard-drawn.
3. That the influence of temperature on their conducting power is very great; so that slight errors in thermometers, or in the reading of them off, would materially affect the result.

In favour of using mercury as a means of reproducing standards the following may be said:—

1. That no molecular change can take place in the metal, nor can any alteration occur in its conducting power, on account of annealing; for its temper is always the same.
2. That the influence of temperature has only a small effect upon its conducting power.

And against it:—

1. That there is a difficulty in obtaining absolutely pure mercury; so that the results obtained by different observers show great variations.

2. That the standard tube cannot be kept full of mercury for any length of time, owing to the diffusion of impure metal, arising from the amalgamated terminals into the narrow tube; so that each time the standard has to be used, it must practically be remade.

3. If the tube be broken during the process of cleaning or otherwise, it is not yet certain with what exactitude the standard could be reproduced.

4. It is doubtful whether the resistance of a tube filled with mercury today will have the same resistance if filled a year hence; for we have no proof if the dimensions of the tube will not alter by being kept. It is well known that the bulbs of thermometers are liable to change, and are continually changing, in capacity.

In favour of the gold-silver alloy may be said:—

1. That this material, when prepared and drawn by different persons, was found not to vary in its conducting power more than 1·6 per cent.; whereas the variations found with the metals in a solid state, prepared and drawn by different persons, amounts to several per cent., and those found for mercury by different observers amount also in all cases to several per cent.

2. That the homogeneity and molecular condition of this alloy are always the same.

3. That the effect of annealing on the conducting power is very small, being only 0·3 per cent.; so that if a wire be partially hard-drawn, its conducting power will not suffer to any appreciable extent.

4. That the influence of temperature on its conducting power between 0° and 100°, viz. a reduction of 6·5 per cent., is smaller than either that of the metals in a solid state, viz. 29·3 per cent., or that of mercury, viz. 8·3 per cent.

And against it:—

That the conducting power may alter by age, as the physical properties of alloys are more likely to change than those of metals.

From the foregoing statements, based on facts at present known, it would appear that the best method of reproducing standards, for those who are unable to procure copies of the British Association unit of electrical resistance, is that they should make, or have made, a certain amount of the gold-silver alloy (as described in the Phil. Mag., Feb. 1861), by two or three different persons, in order to ensure a correct result, and take a given length and section or weight of it, at a given temperature, which has been found equal in resistance to the British Association unit. We would recommend, in order further to test what we have stated in the foregoing Report, that three or more scientific men and electricians be requested to compare the resistances of pure mercury, obtained by them from the best sources they are able, and of the gold-silver alloy (made in the manner described in the Phil. Mag.) with a German-silver standard supplied to them by your Committee. If this be done, results would be obtained which would put an end to many disputes on the subject, as well as decide which of the above means is practically the best for reproducing standards of electrical resistance where no copies of the British Association unit can be obtained.

APPENDIX D.—Professor KIRCHHOFF's *Letter.*

To Fleeming Jenkin, Esq.

Heidelberg, June 8, 1862.

DEAR SIR,—I have the honour to acknowledge the receipt of your letter of the 31st of May, in which you inform me of the labours of the Committee appointed by the British Association, to try and bring about the general introduction of one unit of electrical resistance. I gladly respond to the invitation to express my view on the manner in which the desired object might be best attained.

To define the unit of resistance by the resistance of a wire of given dimensions of a pure metal appears to me impossible, for the reasons which have been urged by the Committee; hence, of the three proposals discussed by the Committee, there only remain two for our consideration.

1. To adopt the unit proposed by Weber; or, 2. To establish, as unit of resistance, the resistance of a column of pure mercury of given dimensions and at a given temperature.

I do not think that to these a third of equal value can be added; for to define the unit of resistance by the thermal action of an electrical current would certainly never answer the purpose, because this thermal action cannot be measured with the necessary accuracy, and the resistance of any wire which is to be permanently kept cannot be fixed as unit; for the resistance of any wire for a given temperature certainly undergoes changes if electrical currents are transmitted through it, and it is exposed to fluctuations of temperature.

Of the above two units, the first recommends itself by coming up more satisfactorily to the demands of science; the second, as I think, by being capable for the present of being practically carried out with greater accuracy. But is it really necessary to decide for one and against the other of these two units? I think not. If the ratio between them is established with the accuracy which is now attainable, there can, I think, arise no more confusion from their simultaneous use, than from the practice of expressing lengths sometimes in metres and sometimes in millimetres. You say, "It is proposed that the unit adopted shall be represented by one particular standard, constructed of very permanent materials, laid up in a national repository;" and further, "The Committee will probably endeavour to devise some plan by which copies of the actual material standard adopted may be easily procured at a reasonable cost." This plan, the execution of which I consider highly desirable, might evidently be realized in all its essential points without its being necessary to give the preference to one of these units over the other: it would only be necessary to measure the resistance of the normal standard in *both* units, and to add to each copy its resistance expressed in *both* units.

In choosing the metal or the alloy of which the normal standard and the copies are to be made, care must undoubtedly *first* be taken that the resistance is as unalterable as possible for *one* temperature. It is undoubtedly desirable that the resistance shall not vary rapidly with the temperature. This is, however, not very important, provided that the temperature of the wire can be accurately observed at any moment. To satisfy this condition, the wires must not be coiled upon cylinders, but fastened so that, for the greater part of their extent, they lie clear, and hence rapidly assume the temperature of the surrounding air or of the non-conducting liquid in which they may have been immersed.

You request me to point out to you any researches of mine which refer to a unit of electrical resistance. I have to mention a short treatise only, which appeared in vol. lxxvi. of Poggendorff's 'Annalen,' under the title "Determination of the Constants on which the Intensity of Induced Electrical Currents depends," and which formed the answer to an academical prize-question which Professor Neumann, in Königsberg, had proposed in the year 1846. In this treatise a unit of electrical resistance has not been suggested; but in it the resistance of a wire has been measured by the unit (or rather by double the unit), which was afterwards proposed by Weber in his "Electrodynamic Measurements." Professor Weber has subsequently had the kindness to compare the copper wire whose resistance I measured, with those whose resistances he himself had determined (Pogg. Ann. vol. lxxxii. p. 360); he thereby found the resistance of my wire about one-seventh greater than I had found it. The reason of this want of agreement consists partly in the imperfection of the instruments which I had used, and partly in the fact that in my experiments the temperature was little above 0° R., while in Weber's experiments it was about 20° R.

Allow me, my dear Sir, to record the very great respect with which I have the honour to be,

Yours very truly,
G. KIRCHHOFF.

APPENDIX E.—DR. SIEMENS'S *Letter.—Suggestions for the adoption of a Common Unit in measurement of Electrical Resistance.*

To the Committee appointed by the British Association to report on Standards of Electrical Resistance.

GENTLEMEN,—I beg to acknowledge, with thanks, the honour you have done me, in requesting me to furnish you with suggestions in furtherance of your endeavours to procure the adoption of a common unit of electrical resistance.

I proposed in Poggendorff's Annalen (vol. cx. p. 1) to supply this want by the adoption of the conducting power of mercury as unit, and of the resistance which a prism of that metal a metre long, and a square millimetre section, at 0° C., opposes to the passage of a current, as unit of resistance.

The method by which I constructed standards in this unit was as follows:

From the ordinary glass tubes of commerce, pieces were selected whose calibre was found to vary most regularly. After the selected tubes had been ground to the length of a metre, they were carefully cleaned and filled with pure mercury—the temperature being measured. The contents were then weighed, and the values reduced to 0° C. for expansion of glass and metal. The resistances of the tubes were calculated by the formula

$$W=\frac{l\sigma}{g}\cdot\frac{1+\sqrt{a}+\frac{1}{\sqrt{a}},}{3}$$

which represents the resistance to a current in the longer axis of a prismatic conductor either in the above unit or in 0·001 unit, according as l is expressed in metres and g in grammes, or l in millimetres and g in milligrammes respectively. $\sigma=13{\cdot}557$, the specific gravity of mercury, at 0° C.

$$\frac{1+\sqrt{a}+\frac{1}{\sqrt{a}}}{3}$$

is the coefficient for conicalness, which in good tubes equals 1, very nearly. a is the ratio of the greatest to the least transverse section of the tube.

All the data therefore necessary for the value of W are exact measures of length and weight. Measurements of the same tube, at different times, gave results corresponding within 0·01 per cent. with each other.

The first objection which is raised against the adoption of mercury as unit, "that the tubes cannot be made of uniform or similar wires, and that the standard once broken is lost for ever," is clearly untenable, since the tubes are not required to be uniform, and the breakage of the standard involves only the necessity of a new tube, and the determinations of length and weight anew, to put the operator in possession of a new standard, whose agreement with the broken one will depend solely on his own handiness in manipulating. Every standard, of whatever material, is liable to injury; but the breakage of a glass is infinitely to be preferred to the treacherous results of a bruised wire.

Mercury is, of all metals, that which is best suited to supply a reproducible standard.

In the first place, it is procurable *pure* in sufficient quantities. I heated for some hours samples of commercial mercury under sulphuric acid containing a few drops of nitric acid, and found their conducting powers afterwards to be precisely the same as that of a quantity of chemically pure mercury reduced from the oxide.

Secondly, mercury has always the same molecular structure, and has therefore, at the same temperature, always the same resistance.

From these two grounds it is possible to couple with this unit a geometrical conception which is indispensable in practice.

Thirdly, of all metals capable of being used for resistances, mercury has the lowest conducting power; and of all pure metals capable of the same application, its resistance varies least with variations of temperature.

Having formed such original standards, it only remained to copy them in a convenient form for employment in practice. This I have done,—

1. In mercury contained in glass spirals, and
2. In German-silver wire.

The resistance-bridge which I made use of in these measurements, with a reflecting galvanometer in its circuit, enabled me to attain a precision of within 0·01 per cent.

The mercury spirals, as may be seen by the accompanying drawing*, are provided with cups at their ends. for convenience of filling and for receiving the contacts of the measuring apparatus. They are either of known resistances, approximating only to a multiple of the unit, or may be adjusted to an exact multiple by boring out one of the ends of the tube, which, in this case, must stand up half an inch inside the cup. The resistances of the bridge must then be arranged so that no current passes through the instrument only when the desired resistance in the fourth side is reached. When the spiral is filled, a vulcanized india-rubber ring is put round the cups, and the spiral is suspended in a vessel of ice-water or water kept in circulation by passing a current of air through it, and the temperature measured by a delicate thermometer.

The electrical value of each spiral which I have made has been determined by comparing it with at least two of the straight normal tubes, both being kept during the measurement in ice-water. The greatest differences which I have found between such determinations do not exceed 0·05 per cent., to which limit the copies may be trusted.

In answer to the objection that an admixture takes place between the mercury and the solid metal used for the terminals, I must remark that I have found this occasion really less inconvenience than is generally believed. I kept the copper connexions immersed in the mercury a whole week, but could not perceive the slightest decrease in its resistance. Platinum electrodes of considerable surface might be employed; but I believe that the removal of the copper connexions after each test, and the removal of the old mercury from their surfaces before using them again, are a sufficient safeguard against error arising from this source. Besides, it is easy to fill the spiral with fresh mercury whenever it is suspected to have dissolved any quantity of copper, or even on every occasion when a measurement with it is to be made. Nor does mercury change its resistance in the least by standing in the air. This I have proved by keeping a spiral six months filled without changing the mercury, and found its resistance to be constant.

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* The drawings have been omitted, the descriptions being intelligible without them.

The material which I have extensively employed in copying this measure, viz. German silver, may be classed under the same head as the expensive gold-silver alloy of Dr. A. Matthiessen, over which it has, however, the considerable advantages of a greater specific resistance, and that its resistance varies less with temperature variations.

As a preventive against alteration of resistance by the influence of the air, I have usually had the resistances made of this metal covered with a coating of silk and lac.

Intermediate between the resistances to be measured and the measure itself, I have introduced resistance-scales. These contain each a series of resistances (multiples of the unit), and are so arranged that each resistance is exact when it stands stopped alone in the circuit. When carefully made, these scales may be depended on to 0·1 per cent.

Being convinced of the sufficiency of the method I have described of reproducing a standard of electrical resistance, I have the honour to suggest to you,

1st. To recommend the universal adoption of the conducting power of mercury as unit, and of the resistance which a prism of that metal, a metre long, and square millimetre section, at 0° C., opposes to a current of electricity as common unit of resistance.

2nd. To have the value of this measure ascertained, with the greatest possible exactness, in absolute units.

3rd. To have copies of this unit constructed in mercury contained in glass spirals for preservation in scientific repositories.

In the event of my suggestions being adopted, the mercury unit should be determined again with the greatest possible care, and with all the help which pure and applied science offers, and copies of it made with equal exactness.

According to a late determination by Weber, the mercury unit is only about $2\frac{1}{2}$ per cent. greater than 10^{10} absolute units, or one mercury unit at $-26°$ C. would equal 10,000,000,000 absolute units.

Since those cases in which the expression of resistances in absolute measure is of advantage in facilitating calculations occur only very seldom, and only in purely scientific exercises, a single determination of the relation of the two measures would be amply sufficient. Should the absolute unit or any multiple of it be adopted as common unit of resistance, there would still be wanted a unit for expressing the conducting powers of bodies; and mercury is indisputably the best calculated for this purpose. And for practical purposes, which in adopting a universal unit should be principally taken into consideration, it is indispensable to define the resistance-measure as a geometrical body of that material which is selected as unit of conducting power. Every other definition would not only burden unnecessarily the calculations which occur in common life, but also confuse our conception of the measure.

The reason why the arbitrary unit proposed by Jacobi (a length of copper only *approximately* defined) found no admittance into general use is to be sought in the fact that it failed to fulfil this condition, and because the conucting power of all solid bodies is too dependent on their molecular structure.

The same objection renders the adoption of the gold-silver alloy proposed by Dr. A. Matthiessen equally incapable.

Another disadvantage in the way of a solid metal unit is the impossibility to solder thick connexions into the ends of a defined length of any wire without altering its resistance.

Should the adoption of the mercury unit be deemed advisable, I would place at the service of the British Association any further information or assistance in my power.

I have the honour to be, Gentlemen,
Your most obedient Servant,
W. SIEMENS.

APPENDIX F.—*Extracts from a Letter addressed to* Professor WILLIAMSON *by* Dr. ESSELBACH.

The two objections against the practical applications of Weber's absolute unit have been sufficiently pointed out as being—

1. Its minuteness; and
2. That the electromotive force of galvanic elements does not allow of variation (as strength of current, tension, and resistance do), but that we have to accept certain constants as nature has fixed them.

I take it for granted that the standard of absolute unit would not lose in authority if a plain multiple of it were adopted. I need not point out that the French metre itself is only a submultiple, $\frac{1}{10,000,000}$th of a natural unit—the earth's quadrant. The multiple of the natural electro-magnetic unit I am about to suggest for practical use is 10^{10}, therefore very simple (which is of no little importance); and it is a multiple which leads us to those standards which are practically used.

M. Bosscha gives the electromotive force of his Daniell's cells in absolute measure as

$$1025{\cdot}80 \,.\, 10^8,$$

and calculates the one used by Mr. Joule to be

$$1045{\cdot}1 \,.\, 10^8.$$

It will therefore be practicable to determine such concentration of sulphuric acid as to make the electromotive force equal to

$$10 \,.\, 10^{10};$$

and I believe the concentration required would be very near what is actually used in telegraphy.

Resistance.—The different copies of Jacobi's étalons are well known to differ as much between each other as Daniell's cells; and if Siemens had done nothing else for galvanometry than to give us copies which agree among themselves within a quarter per cent., the progress is obvious.

Weber's copy of Jacobi's étalon is

$$598 \,.\, 10^7;$$

and that of M. Bosscha was

$$607 \,.\, 10^7$$

in absolute measure.

Other statements (of Kirchhoff and others) give a much smaller value.

In comparing Mr. Siemens's mercury standard with three copies of Jacobi's étalon in his possession, I found two of them agreeing tolerably well with each other, and with a third one copied by my friend Dr. Teddersen, at Leipzig, from the original of M. Leyser, which I took therefore to be the more correct ones. I found the absolute value of Siemens's unit to be

$$\frac{603}{660} \cdot 10^{10},$$

or

$$1\cdot1 \text{ Siemens's unit} = 10^{10}.$$

We should therefore only have to multiply all observations expressed in Siemens's units by $\frac{10^{10}}{1\cdot1}$ to reduce them to absolute measure, and the suggested multiple for the future standard would not be far from 1·1 of Siemens's units, which every one admits to be for metallic conductors a practical unit.

For the resistance of insulating materials the figures become impracticably high; but it would be a matter of professional telegraphy to adopt, in conformity with the system, the 'resistance' 10^{10} and, besides, another 'great resistance' containing 10^{10} 'resistances.'

While the resistance of a mile of copper in an ordinary cable would be (say) 4 R. (four resistances), the insulation-resistance of a mile of cable would be about 0·04 G. R. (great or gutta-percha resistances).

My suggestion would therefore be—

1. To adopt Weber's absolute unit, and to derive from it, by the multiple 10^{10} (or 10,000,000,000), the practical unit.
2. To adopt 10^{10} of Weber's electro-magnetic units as the 'practical absolute unit' for electromotive force and resistance.
   (10 of these units would be exactly 1 Daniell's cell.)
3. 1 of these units would be 1·1 of Siemens's units.
4. To allow, besides, a 'practical great unit,' viz. 10^{10} of the 'practical units,' for resistances in order to express the insulation-resistance of cables in convenient figures.
5. To allow also a 'practical small unit' of $\frac{1}{10^{10}}$ absolute units to express insulation-currents and charge-quantities of cables in convenient figures.
6. To adopt, in order to avoid confusion, for such 'practical units' a terminology as proposed by Messrs. Bright and Clark.

London, September 18, 1862.

APPENDIX G.—*Circular addressed to Foreign Men of Science.*

SIR,—I am requested to inform you that a Committee was appointed by the British Association, which met last year at Manchester, to report on Electrical Standards of Resistance.

The Committee consists of the following gentlemen:—

Professor A. W. Williamson, F.R.S. (University College, London).
Professor Charles Wheatstone, F.R.S. (London).
Professor William Thomson, F.R.S. (Glasgow).
Professor W. H. Miller, F.R.S. (Cambridge).
A. Matthiessen, Ph.D., F.R.S. (London).
Fleeming Jenkin, Esq. (London).

The Committee met on December 6th, 1861, and on April 3rd, 1862. On the latter occasion the following Resolution was passed:—

> "*Resolved*,—That the following gentlemen be informed of the appointment of the present Committee, and be requested to furnish suggestions in furtherance of its object.

Professor Edlund (Upsala).
Professor Th. Fechner (Leipzig).
Dr. Henry (Washington).
Professor Jacobi (St. Petersburg).
Professor G. Kirchhoff (Heidelberg).
Professor C. Matteucci (Turin).
Professor Neumann (Königsberg).
Professor J. C. Poggendorff (Berlin).
M. Pouillet (Paris).
Werner Siemens, Ph.D. (Berlin).
Professor W. G. Weber (Göttingen)."

I have, in consequence, the honour of addressing you the present letter.

The Resolutions passed at the two meetings are enclosed, and from them you will gather the general scope of the Committee's inquiry. I add some further explanation as to the object and intentions of the Committee.

Great inconvenience has been felt from the absence of any generally adopted unit for the measurement of electrical resistance, and it was thought that the influence of the British Association might be successfully exerted to procure the adoption of a common standard. The present time was thought especially favourable, since, although the methods of observation have been brought to great perfection, no local units have as yet taken very deep root.

The units which up to the present time have been considered by the Committee may be classed under three heads:—

1st. A given length and weight or section of wire made of some pure metal, and observed at a given temperature, as originally proposed by Professors Wheatstone, Jacobi, and others.

2nd. Units based on Weber's and Gauss's system of absolute measurement.

3rd. A given length and section of pure mercury at a given temperature.

Whatever basis is adopted for the unit, it is proposed that the unit adopted shall be represented by one particular standard, constructed of very permanent materials, laid up in a national repository; and it has been proposed to use Dr. A. Matthiessen's gold-and-silver alloy for this purpose. The arguments which have been used for and against these systems are as follows:—

In favour of the use of a wire of some pure metal it is said—

That the plan is the simplest possible, and admits of independent observers forming their own standard.

Against the plan it is said—

1st. That even when pure, two apparently similar wires do not resist equally unless their temper or molecular condition be the same—a condition which cannot practically be ensured.

2nd. That there is reason to believe that the resistance of a given wire is not constant even at a constant temperature.

3rd. That the resistance of all pure metals varies very rapidly with the temperature.

4th. That great difficulty is found in obtaining any metal pure, and that the attempt of most persons to reproduce the unit for their own use would be attended with incorrect results. This is evidenced by the different relative results as to the resistance of pure metals published by different observers.

In favour of Weber's units it is urged—

1st. That their use will ensure the adoption of a complete system of corresponding standards for electrical currents, quantities, and tension or difference of potential.

2nd. That their use is essential in the dynamic treatment of any problem connected with electricity; for instance, in determining the heat generated, the force exerted, the work done, and the chemical action required or produced under any given circumstances.

3rd. That their use would be a simple extension of the system already universally adopted in magnetic measurements.

4th. That the unit is independent of the physical properties of any material.

Against the system it is urged that the unit cannot be determined with sufficient accuracy, and that even its approximate reproduction, where copies cannot be obtained, is difficult and expensive.

In favour of the mercury standard the following arguments are used:—

1st. No change can occur in the molecular structure or temper of the material, and therefore the same tube filled with pure mercury will certainly always conduct alike.

2nd. Change of temperature causes only a slight difference in resistance.

Against this plan it is said—

1st. That tubes cannot be made of uniform or similar wires, and that, therefore, the standard once broken is lost for ever.

2nd. That the standard tube cannot be kept full of pure mercury, owing to the admixture which would take place of the solid metal used for the terminals, so that each time the standard has to be used it has practically to be remade.

3rd. That the attempt, by most observers, to reproduce the unit for their own use would be attended with incorrect results, as is shown by the different results obtained by different observers.

In favour of Dr. Matthiessen's alloy, as compared with wires of pure metal, or with mercury, as a material for the standard, it is said—

1st. That the variations of resistance, corresponding with variations of temperature or temper, are small.

2nd. That a unit expressed in this material can be more readily and certainly reproduced than one expressed by a pure metal, because the presence of slight impurities in the component metals, or a slight change in their proportion, does not sensibly affect the result.

Against this plan it is said that the physical properties of an alloy are more likely to change than those of a pure metal.

Against all the plans for standards, based on an arbitrary length and section of an arbitrary material, the supporters of the absolute units state that the adoption of such an arbitrary standard would lead to great confusion and complication in the measurement of all other electrical properties, and in the expression of the relation of such measurements to those of force, work, heat, &c.

This objection does not, of course, apply to the expression of the absolute unit by means of a wire of pure metal, of an alloy, or by mercury: but it is urged that no observer should ever attempt the reproduction of a standard when a copy of the proposed universal standard can possibly be obtained; and the Committee will probably endeavour to devise some plan by which such copies of the actual material standard adopted may be easily procured at a reasonable cost.

It will be seen from the resolutions passed, that the Committee are now engaged in investigating the degree of accuracy with which Weber's units can be obtained, and the degree of permanency which may be expected from the use of the metal or alloy forming the material standard expressing these or other units.

The Committee will feel greatly indebted to you if you will afford them the benefit of your valuable advice and experience on the above points, and on any others which may occur to you. They also venture to hope that such a standard may be selected as will give very general satisfaction; and, if approved by you, that you will kindly take an interest in procuring its general adoption.

Personally being charged with the duty of preparing an historical summary of the various units proposed, I shall be grateful if you will favour me with any remarks as to your own labours in this field, or if you could oblige me with references to any papers or works in which the subject is treated.

I am, Sir,
Your obedient Servant,
Fleeming Jenkin.

Appendix H.—*Description of the Electrical Apparatus arranged by* Mr. Fleeming Jenkin *for the production of exact copies of the Standard of Resistance.*

This apparatus is a simple modification of that generally known as "Wheatstone's bridge." It contains, however, some special arrangements, in virtue of which various practical difficulties are avoided, so that very great accuracy can be ensured with comparative ease. The usual bridge-arrangement is shown in Plate I. fig. 9, where the irregular scrolls, A, C, R, S, represent the four conductors of which the resistance is to be compared; the thick black lines show those portions of the circuit which join the coils with the four corners, U, V, Z, Y, and are supposed to have no sensible resistance in comparison with the coils; finally, the thin lines show connexions, the resistance of which in no way affects the accuracy of the comparison between the four coils. By this arrangement the four conductors, A, C, R, S, are so connected with the galvanometer, G, and the battery, B, that no current passes through the galvanometer when the conductors bear such a relation to one another that the equation $\frac{A}{C}=\frac{S}{R}$ holds good; whereas a current in one or other direction passes so soon as $\frac{A}{C}$ is greater or less than $\frac{S}{R}$*. Thus the direction and strength of the current observed serve as guides by which the resistance of any one of the conductors may be gradually adjusted by shortening or lengthening the wire, until on the completion of the circuit no deflection whatever can be observed on the galvanometer, however delicate it may be, or however powerful the battery used. When this has been done, we may be sure that the above relation exists between the four conductors. In practice, it is seldom desirable to use powerful batteries; the test is made delicate by the use of an extremely sensitive astatic galvanometer.

In speaking of the four conductors, A, C, R, S, which are generally all coils of wire of similar construction, although each fulfilling a distinct function, some difficulty often occurs in explaining readily which coil or conductor is referred to. They can of course be distinguished by letters, but this requires reference to a diagram on every occasion, and the writer has therefore been in the habit of distinguishing the four coils by names drawn from a very obvious analogy existing between this electrical arrangement and the common balance in which one weight is compared with another. The equality between the two weights on either side of a balance, when the index is at zero, depends on the equality of the arms of the balance; and if the arms are unequal, the weights required to bring the index to zero are proportional to the arms (inversely). Let A and C be called the arms of the electrical balance, while S and R are looked on as analogous to the standard weight and mass to be weighed respectively, and let the galvanometer needle stand for the index of the balance. Then all the above statements, with respect to the weights and arms, hold good for the electrical arrangement (except that the proportion between the electrical arms and weights is direct instead of inverse). The writer therefore calls this arrangement an electric balance—A and C the arms, S the standard, and R the resistance measured*. In the adjustments of resistance-coils or copies of a standard, the object is to produce a second coil, R, exactly *equal* to the first or standard, S; and the arms, A, C, must therefore be absolutely equal before, by this arrangement, an exact copy can be made. Hitherto it has often been the practice to use for the arms, A, C, two coils made as equal as possible, and placed so close as to remain at sensibly equal temperatures; so that the equality between R and S is dependent on the equality between A and C, and cannot be determined with greater accuracy than that between these coils. This limit to the accuracy is a defect for our present purpose, and the writer has moreover found it undesirable to depend on the permanent equality of two coils. It is by no means certain that, without very extraordinary precautions, the two arms will remain unaltered in their original equality. A slight molecular change, or a slight chemical action on the surface of the wires, disturbs this equality permanently; and even if the coils are so constructed as to remain really equal at equal temperatures, the accidental passage of a current through one arm, and not through the other, for a very short time, will disturb their accuracy very sensibly for a considerable time. There are various devices by which the equality to be established between R and S may be rendered independent of the absolute equality between A and C, and the writer has adopted a plan, now to be explained with the aid of the diagrams (figs. 7, 8). This plan allows the approximation to equality between R and S to be almost indefinitely increased.

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* This statement holds good also if the battery and galvanometer wires, as shown in diagram, are interchanged.

It will be seen that fig. 7 does not differ from fig. 9, except by the addition of a wire, WX, of sensible resistance, between the two coils A and C. The point U is no longer fixed, but can be moved along WX. The arms of the balance are therefore no longer A and C, but $A+XU$ and $C+WU$. Thus the moveable point U affords the means of slightly altering or adjusting the ratio of the two arms. A and C are made as equal as possible, independently of WX, which is a very short wire.

The test is made as follows:—When the standard and coil to be measured have been put in their places as in fig. 7, the point U is moved along the wire WX until the galvanometer-index is not deflected when the circuit is closed. The position of the point U is noted by a scale. R and S are then reversed, so as to occupy the position relatively to A, C shown in fig. 8. The point U is again moved until the galvanometer-needle remains undeflected on the circuit's being closed. The new position of U is again observed by a scale. If the point U does not require to be moved at all, we may be quite sure that R is exactly equal to S, and that $A+XU=C+WU$, since it would be quite impossible that the ratio $\frac{A+XU}{C+WU}$ should be equal to both $\frac{R}{S}$ and $\frac{S}{R}$, unless this ratio were equal to 1. Moreover, if WX be made of the same

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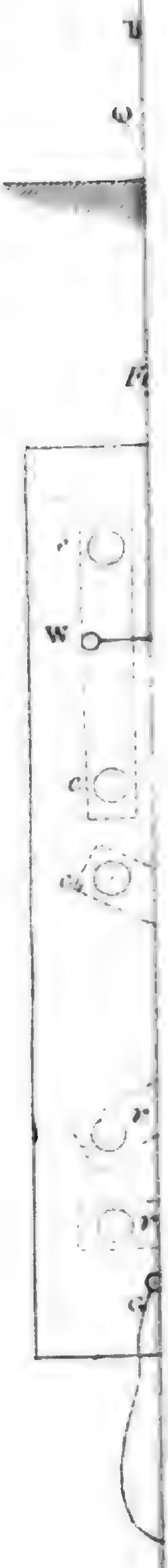
* The name of parallelogram, sometimes given to the arrangement, is objectionable, inasmuch as the relation obtaining between the four conductors is not that which exists between the four sides of any parallelogram, except in the one case of equality between all four conductors. The connexions are, however, most easily followed in a drawing when arranged as the four sides of a quadrilateral figure. Professor Wheatstone's original name of Differential Resistance Measurer does not, as it seems to the writer, sufficiently distinguish this arrangement from other differential methods.

Full siz


U
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W
c
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r
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G

J. W. Lowry

Fig. 7. Diagram of connexions when commutator is in position drawn (Fig. 1.) d connected with d₁ & f with f₁

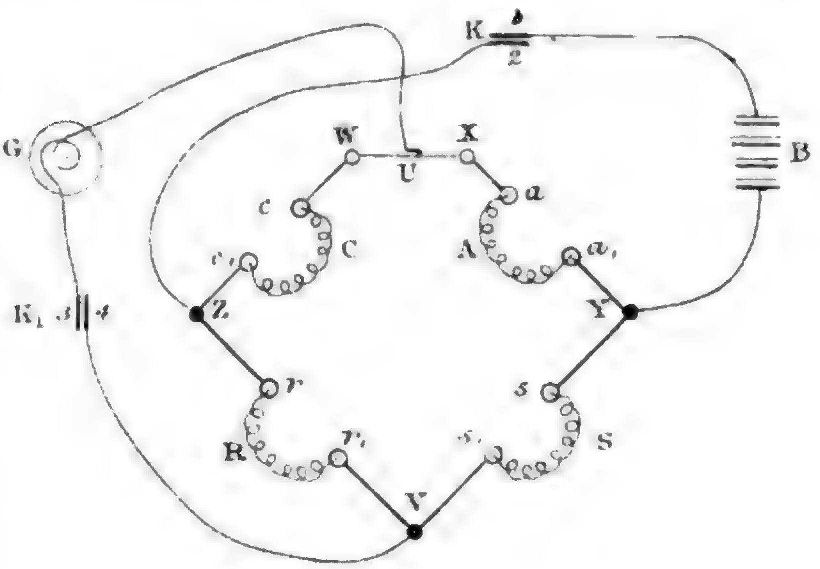
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Fig. 8. Diagram of connexions with commutator D placed across board, d connected with f & d₁ with f₁

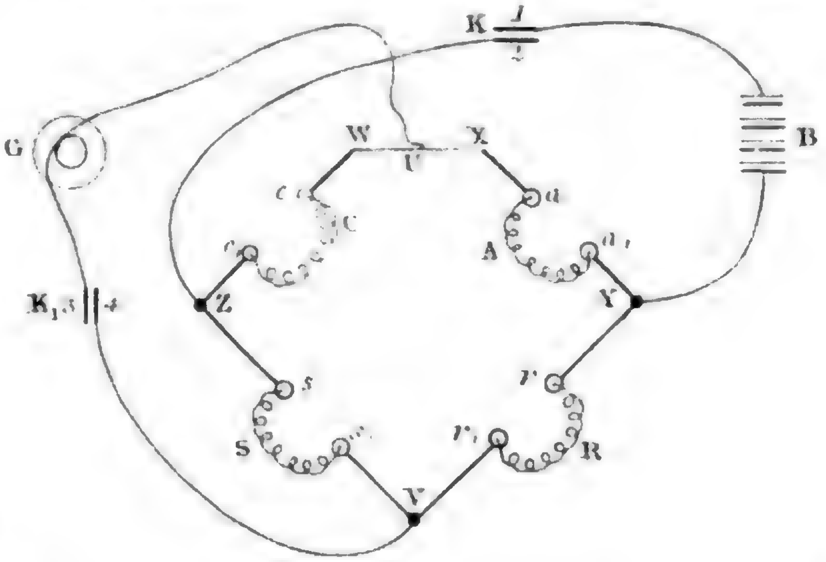
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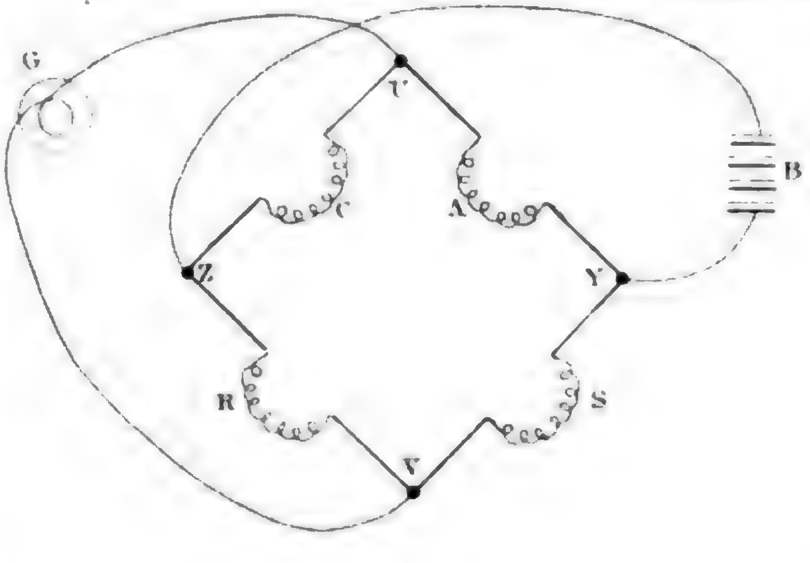
Fig. 9. Common Bridge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wire as the coils A and C, and if those coils are formed of about 100 inches of wire, and if the observed positions of U differ by a given distance, x, this length, x, measured in inches, will express very nearly the difference between R and S in a percentage of the whole length of R. Thus, if x be one inch, the standards S and R differ by about one per cent. If the point U, when adjusted in each case, be found nearer R than S, then R is the smaller of the two, and *vice versâ*. The percentage of error in R, thus measured, is not of course strictly accurate, inasmuch as the ratio between the two arms is not exactly $\frac{101}{100}$; but if WX be not more than three or four inches long, the percentage of error measured in this way is quite sufficiently accurate to allow the new coil to be so exactly adjusted after very few trials, that no greater movement of U than (say) $\frac{1}{10}$th of an inch is required to prevent any deflection on the galvanometer when R and S are reversed. We may then be sure that no greater error than (say) about 0·1 per cent. exists in the equality between the new coil and the standard. Two fresh coils, A_1, C_1, are then taken, containing each about 1000 inches of wire similar to WX, or an equivalent resistance. It will then be found that, to maintain the index at zero when R and S are reversed, U must be moved about ten times as much as before, or (say) one inch. R can then be still further adjusted till U is not moved more than $\frac{1}{10}$th of an inch, when a new degree of approximation to equality, with an error of not more than 0·01 per cent., will have been reached. Then the coils A_1, C_1 are changed for a fresh pair, A_2, C_2, with a resistance equal to about 10,000 inches of the wire WX: one-tenth of an inch on WX will then represent an error of only 0·001 per cent. By a repetition of this process, quite independently of any absolute equality between the pairs A, C, A_1, C_1, A_2, C_2, &c., a gradual approximation to any required extent may be ensured. The delicacy of the galvanometer used, and the nicety of the means available for increasing or diminishing the resistance of R, form the only limits to the approximation. A slight want of equality between any pair of arms will simply bring the point U a little to one side or the other of the centre of WX, as the final adjustment with that pair is made, but will not affect the truth of the comparison between R and S. Each pair must, however, be so nearly equal that the addition of part of the short wire, WX, to one side will be sufficient to correct the other; otherwise the adjustible point U would not bring the index to zero, even when at one end of the wire.

This arrangement, besides rendering us independent of the accuracy of any two arms, has some incidental advantages of considerable practical importance. At each test it gives a measure of the amount by which the new coil to be adjusted must be lengthened or shortened. The test is at first comparatively rough, or adapted to errors of one or two per cent., and only gradually increases in delicacy as the desired equality is more and more nearly approached. It is not necessary that the resistance of WX should remain absolutely constant, since it is only used (numerically) to give a rough approximation to the percentage of error. It is desirable that the battery should remain in circuit as short a time as possible; the circuit is therefore broken between 1 and 2, figs. 7 and 8, by a key, K, with which contact should be only momentarily made, when all the other connexions are complete. The direction of the jerk of the galvanometer-needle to one side or the other need alone be observed; no permanent deflection is required with this arrangement as a guide to the amount of error. This is a considerable advantage, inasmuch as it avoids heating the wires, and saves time. The induction of the coils on themselves might lead to some false indications, unless special precaution were taken against it, as pointed out by Professor W. Thomson*. To avoid this source of error, the galvanometer circuit is broken between 3 and 4, figs. 7 and 8, at K_1, and should only be closed after the battery circuit has been completed at K and equilibrium established throughout all the conductors.

Before passing to a detailed description of the apparatus as actually constructed, some remarks are required as to the means of making temporary connexions. All connexions which require to be altered may be the means of introducing errors, inasmuch as the points of contact are very apt to offer a sensible but uncertain resistance. In measuring small resistances, the resistance at the common binding-screws is found to create very considerable errors. Binding-screws have therefore to be avoided at all points where an uncertain resistance could cause error. Mercury-cups, made as follows, have been found in practice very suitable for temporary connexions, and have been adopted in the apparatus. The bottom of each cup is a stout copper plate, with its surface well amalgamated, forming one of the two terminals to be joined. A stout copper wire, $\frac{1}{4}$ inch in diameter, with a flat end well amalgamated, forms the other terminal. When the amalgamation is good, and care is taken that the wire shall rest on the plate, this form of connexion offers no sensible resistance. The amalgamated wire is easily kept bright and clean by being dipped from time to time in a solution of chloride of mercury and wiped. The copper plate should also be removed from the cup, cleaned, and re-amalgamated occasionally. All permanent connexions should be soldered.

The apparatus itself, as actually constructed, will now be described (figs. 1 to 6). It consists of a wooden board, about 12 in. × 7 in., containing the mercury-cups, the adjusting wire, WX, the key, K, and the terminals to which the battery and galvanometer are connected. The letters in the figures 1 to 6 correspond exactly to those used in the diagrams 7 and 8; and the apparent complexity of the connexions can thus be easily disentangled. cc_1, aa_1 are two pairs of mercury-cups, into which the terminal wires on the bobbin, C, A, dip. This bobbin contains the two coils, C and A, forming the arms of the balance. rr_1 and ss_1 are mercury-cups, into which the terminals of the standard and coil to be adjusted are placed. These mercury-cups are so connected with the four cups, d, d_1, f, f_1, that when d is connected with d_1, and f with f_1, by a couple of wires in a small square of wood, D, then A, C, S, and R are connected as in fig. 7; but when D is turned round, so as to connect d with f, and d_1 with f_1, A, C, R, and S are connected as in fig. 8. D is called the commutator. The same end might be effected without a commutator by simply interchanging R and S; but it is frequently inconvenient to do this. All these connexions are made by short stout copper bars, dotted in fig. 2. The wire WX, the sliding brass piece H, carrying a spring for the contact at U (fig. 4), and the scale E, by which the position of H is observed, will be readily understood from the drawing. The sliding piece, H, is connected with the proper points by the helix of copper wire, h, and the screw, I. $G\,G_1$ and $B\,B_1$ are common binding-screws, to which the wires from the galvanometer and battery are attached. K is the key, by depressing which, first, the battery is thrown into circuit, and then the galvanometer. It consists of three brass springs, 1, 2, 3 (fig. 5), each insulated one from the other, and connected by three screws, 1, 2, 3 (fig. 2), with the necessary points of the arrangement. A fourth terminal, 4 (figs. 2 and 6), is immediately under the free end of the springs, and is armed with a small platinum knob or contact-piece. The three springs are also all armed with platinum contact-pieces, all in a line one above the other (fig. 6). When the finger-piece, T, is pressed down, 1 and 2 are first joined, and then 3 and 4; 3 is insulated from 2 by the vulcanite, Q. All the connexions permanently made, under the board, are shown in fig. 2. Those which have no sensible resistance are stout copper bars, and form the bottoms of the mercury-cups: those of which the resistance is immaterial are made of wire, insulated by gutta percha, and are simply shown as dotted irregular lines in fig. 2; they will be found, on comparison, to correspond with the thin lines on fig. 7. It will also be found that all those parts shown by thick lines in the diagram are made by thick bars or rods and mercury-cups.

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* *Vide* Phil. Mag. August 1862.

Three sets of arms, C A, C_1 A_1, C_2 A_2, are provided; the shortest pair is first used, and U adjusted by the slide, H, till the galvanometer does not deflect when T is pressed down. The commutator, D, is then turned round, and U adjusted afresh. The coil, R, is then altered according to the two positions of U, and this process repeated, using the second and third pair of arms as required, until the desired approximation between R and S has been obtained. An astatic galvanometer, with a very long coil, will, for most purposes, give the best results; and one or two elements will be found a sufficient battery. The construction of R and S recommended, and the precautions to ensure perfect equality of temperature, will form part of next year's Report.

The apparatus, although specially designed for the production of equal coils, is applicable to ordinary measurements of resistances by comparison with a set of resistance-coils; for this purpose the terminals of the resistance-coils should be put in the place of the standard S, and any conductor of which the resistance is to be measured in the place of R. If a comparison by equality is to be made, the wire WX can be used as already described; it is, however, frequently desirable to make a comparison with one arm tenfold or a hundredfold greater than the other, by which means measurements of resistances can be made ten or a hundred times greater or smaller than could be done if equality alone between R and S were measured; for this purpose the three pairs, A C, A_1 C_1, A_2 C_2, are made exactly decimal multiples one of the other, and then, by taking A and C_1, or A and C_2, &c., in the cups $a a_1$ and $c c_1$, the required decimal ratio is obtained. The resistance of the wire WX would, however, falsify this ratio, and it is eliminated by a simple copper rod, which is placed for the purpose between the two cups $e e_1$, and maintains the whole wire WX at sensibly one potential. The commutator also is useless in measurements of this kind, and should be left untouched in the position shown in fig. 1.

The apparatus exhibited was manufactured for the Committee by Messrs. Elliott Brothers, of London, and gives excellent results.

Preliminary Report of the Committee for Investigating the Chemical and Mineralogical Composition of the Granites of Donegal, and the Minerals associated with them.

In accordance with the resolution of the General Committee at the Manchester Meeting, the Committee, consisting of Sir R. Griffith, the Rev. Prof. Haughton, and Mr. Scott, proceeded to investigate "the chemical and mineralogical composition of the granites of Donegal, and the minerals associated with them." In furtherance of this object, Mr. Haughton and Mr. Scott repaired, last Easter, to the northern part of the county, as they had visited the S.W. portion of the district in the summer of 1861. They were accompanied on their tour by Mr. Jukes, Local Director of the Geological Survey of Ireland, who gave them the valuable benefit of his experience and assistance throughout the tour. The exploration commenced at Moville, on the E. shore of Innishowen, whence a section was carried along the N. coast of that peninsula nearly as far as Malin Head. This section exhibited a great thickness of primary rocks, consisting of quartzite and mica-slate, accompanied by several beds of limestone, and a number of beds of igneous rocks, which appeared to be contemporaneous with the sedimentary rocks. These are best exhibited at a place called the Mintiaghs or Bar of Inch, where there are several alternations of quartz-rock and syenite exhibited in an escarpment of several hundred feet in height. This locality is situated about five miles N. of Buncrana. From Buncrana, the granite of Urrismenagh, near Dunaff Head, was visited.

From Milford an excursion was made to the extremity of the promontory of Fanad, lying between Lough Swilly and Sheep Haven, in order to visit the granite of this district. This patch of granite is not a continuation of that which traverses the country in a N.E. and S.W. direction, as it lies to the N. of that axis and exhibits a slight difference in composition from the granite of the central axis. From Milford the route lay to Dunfanaghy; and a section was made across the northern end of the granitic axis of the county at Glen, in which its gneissose character was very strongly exhibited. This was marked in a most decisive manner between Lackagh Bridge and Creeshlagh, where the rock might be observed changing from gneiss, by almost insensible gradations, on the one hand into granite, and on the other into hornblende slate and crystalline syenite. The latter is most highly crystalline at Horn Head, where it contains large quantities of titanic iron. On the return-journey from Dunfanaghy to Letterkenny, it was determined to make two sections across the granite; so that Mr. Haughton and Mr. Scott took the road from Creeshlagh through the Gap of Barnesbeg, while Mr. Jukes took that by Owencarrow Bridge, about four miles higher up the valley.

It having now been found necessary to compare the facts observed with those which were to be observed in other countries, Sir R. Griffith repaired to Scotland in the month of July. Mr. Haughton traversed the centre of Scotland, and paid a visit to Sweden, Finland, and Russia. Both these gentlemen discovered facts strongly confirming the views propounded at the Manchester Meeting, of the similarity of the geological structure of Donegal to that of the Scandinavian peninsula and of Scotland. For this latter fact the Committee had been prepared by the examination of a series of specimens of Scotch granites which had been furnished to them by Sir R. I. Murchison, in accordance with his kind promise made at the last Meeting.

While these tours were in progress, Mr. Scott repaired, for the third time, to Donegal, and spent the month of July in the re-examination of several points connected with the geology of the southern district. He visited the granite of Barnesmore, near the town of Donegal, which is essentially non-gneissose, and is penetrated by numerous pitchstone dykes, some of which are amygdaloidal. Numerous minerals were discovered here, which were in some cases new to the district. In the neighbourhood of Glenties, a considerable quantity of andalusite was found in the mica-slate—a mineral which is replaced near Barnesmore by kyanite, and in the Rosses, near Dungloe, by a white variety of kyanite.

From Dungloe, as head-quarters, the structure of Crohy Head was carefully examined, and also the island of Arranmore, which differs materially in its structure from the mainland of Ireland, from which it is only distant three miles. The southern portion of this island is nearly entirely composed of white granite, penetrated by numerous dykes of syenite and of felspathic porphyry. The strike of these rocks is nearly E. and W., while that of the flaggy quartz-rocks on the northern shore of the island approaches N. and S.

During the course of this tour, two more sections were made across the granite of the main axis, exhibiting the same facts which had been observed before, viz. numerous beds of limestone and of altered slate lying in the granite, stratified nearly conformably with it. These were observed in the centre of Glenveagh, close to Ballaghgeeha Gap, on the pass through the Poisoned Glen from Dunlewy. At Glenleheen, where the same occurrence of non-granitic rocks had been observed in the previous year, four beds of limestone and several beds of slate were discovered. Almost all these beds of limestone contained garnet, idocrase, and epidote in quantity; and at Glenleheen itself, scapolite, a mineral whose occurrence in the British Islands has escaped the notice of modern English mineralogists, was discovered. Inasmuch as the specimens brought home by the members of the Committee from their several tours are very numerous, it is not possible for them to present their complete report at this Meeting. They hope to embody in it some valuable information relating to the granitic rocks of Canada, which Dr. T. Sterry Hunt has kindly offered to supply to them. They have to express their thanks to him and to Mr. Harte, C.E., county surveyor of the western district of the county, who, with the Rev. Frederick Corfield, has afforded them most efficient assistance. They have succeeded in procuring some of the granite of Rockall, through the kindness of the officers of H.M.S. Porcupine, who furnished it to Mr. Harte, and will include its analysis in their paper.

On the Vertical Movements of the Atmosphere considered in connexion with Storms and Changes of Weather. By HENRY HENNESSY, *F.R.S., M.R.I.A., &c., Professor of Natural Philosophy in the Catholic University of Ireland.*

THE labours of the Committee, consisting of Admiral FitzRoy, Mr. Glaisher, and myself, who were appointed, at Manchester, for the purpose of studying the vertical disturbances of the atmosphere with the aid of instruments, have, for the present, been restricted to the work of a single observer. This has arisen from the circumstance that the money-grant appropriated to the Committee has sufficed only to defray the cost of erecting a single instrument. As this instrument is likely to afford opportunities for observing the vertical motions of the atmosphere more completely than has been hitherto possible, it is to be hoped that similar apparatus will before long be in the hands of the other members of the Committee. The fact that all the preliminary work has thus necessarily devolved on the writer of the present Report will sufficiently account also for its provisional nature.

Hitherto the only kind of atmospherical currents which have formed the subjects of definite observation by instruments are those whose existence is manifested by the movements of ordinary wind-vanes and anemometers. But as these instruments indicate horizontal movements exclusively, ordinary winds as well as storms are almost always conceived as currents flowing in perfect parallelism to the earth's surface. It is true that no physical theory of the motions of the atmosphere can be attempted without some considerations which involve the necessity of vertical and oblique motions among the masses of air, as well as horizontal motions; but while direct comparisons of the latter among themselves have continued for many years to be made in different parts of the world, we possess scarcely any such data relative to non-horizontal movements as would enable us to make them subjects of exact inquiry.

The only writer who, as far as I am aware, has hitherto endeavoured to deduce any well-defined results from observation relative to the vertical movements of the atmosphere is M. Fournet, and his studies were almost exclusively directed to the elucidation of the phenomena of some remarkable local winds that frequently prevail among the Alps and in the valley of the Rhone*. A local phenomenon in Ireland † induced me to study the vertical motions of the air in a more general way than was necessary for the explanation of this phenomenon itself; and my first step was an attempt at devising a vane capable of showing the existence and direction of non-horizontal currents. This was a non-registering instrument, and the results obtained were therefore somewhat unconnected; but they seemed to establish some important relations between vertical currents and other atmospherical disturbances‡. Among these, I may be permitted to notice the phenomena which preceded the disastrous gale of February 9, 1861. For many days, at the close of January and beginning of February, the weather was remarkably fine, and no vertical currents were observed; but on the 7th very distinct evidences of vertical disturbance came under my notice, while the air had as yet no remarkable horizontal motion. On the 8th, at 2 P.M., my attention was called to the vane by its shifting round through N. towards N.E., with decided and frequent downward plunges of the disk exposed to the vertical action of the air. It appeared as if showers of cold air were descending; for the thermometer showed at the same time a rapidly falling temperature. While vertical convection had become already highly developed, the horizontal motion of the air was not as yet greater than that of an ordinary brisk breeze.

Next day, during the storm, although the disk of the vane was in constant oscillation from the undulatory motion which my observations had already shown to be a necessary accompaniment of all high winds passing over terrestrial obstacles, no marked prevalence of upward or downward motions could be observed corresponding to the plunges of the disk noticed on the preceding day. The mercury in the barometer had been falling with great regularity during four days before that on which I had noticed the first decided indications of vertical disturbance. On that and the next day, as well as on the very day of the storm, the barometric column was rising, while the temperature was steadily falling. Here the rise in the barometer was accompanied by north-easterly winds, and the air at the earth's surface was thus rapidly mingled with cooler masses descending from above, as shown by the vane; so that the increased pressure was due to the increased density of the entire aërial column above the barometer.

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* See Annales de Chimie et de Physique, tome lxxiv. p. 337; and a *résumé* of his results in a note to M. Martin's translation of Kaemtz's Meteorologie, p. 35.

† Proceedings of the Royal Irish Academy, vol. iv. p. 279.

‡ Atlantis, vol. iii. p. 166; Phil. Mag. for May 1860; and Proceedings R. I. A. for May 1861, p. 232.

Among the phenomena attending the more tranquil conditions of the air, I had noticed in my earlier observations, during the summer of 1857, that upward currents generally prevailed by day, while downward currents became more prominent at night. This alternation was manifestly connected, as shown by the horizontal vane, with the action of land and sea breezes; for at this time the observations were made at a point situated about two miles from the sea-shore. By day, the convection due to the heating of the lower stratum of air in contact with the ground could not take place by equal upward and downward exchanges of masses of air, because the place of the ascending warm air was partly supplied by the lateral influx of colder sea air, which, in its turn, would become sufficiently heated to ascend and give place to a fresh lateral influx. By night, the colder air from the land flowed towards the sea, and its place was filled by descending currents from above. At the same time the warmer air from the sea probably tended to occupy the place of these currents, and thus to equalize the temperature of the upper and lower strata of air so as to lessen the energy of the convective movement over the land.

Before the termination of the Meeting of the Association at Manchester, I had resolved, with the concurrence of Mr. Glaisher, the only other member of the Committee then present, to cause a registering instrument to be constructed which would record the existence of non-horizontal atmospheric motions. The following is a description of the anemoscope which I ultimately decided upon as most suitable in its construction for the purposes we have in view. Fig. 1 is a vertical section of the portion of the apparatus which is exposed to the wind, and fig. 3 an elevation of the same portion. A is a cast-iron pillar which supports a cup, *h*, containing friction-balls made of gun-metal; on these a disk, *g*, rests, and this is firmly attached to a box from which an arm projects at one side, and is terminated by the cone, P, which acts as a counterpoise for the opposite and working arm of the anemoscope. A short arm, *n*, shown in fig. 3, supports a wheel, *d*, in one side of which teeth are cut; the other side is firmly attached to a hollow light copper box, B, which forms the tail. This box is a truncated pyramid, and while its vertical sides are exposed to the horizontal action of the wind, its upper and lower surfaces are exposed to its vertical action. This tail is balanced by a counterpoise, *i*, which is connected by a bent arm with the axle of the wheel, *d*. The teeth of this wheel catch those of the pinion, *e* (fig. 1), and this catches in the rack, *f*. The rack is attached to a shaft, *c*, which descends through the hollow supporting pillar and communicates with the registering apparatus. In fig. 2 the most essential part of the arrangements for registering the indications of the upper part of the instrument are shown. The shaft, *c*, passes through brass guides, and carries a small circular projecting piece, *s*, which catches in a notch made in the bit, *v*, attached to the pencil-carrier, *p*. This pencil-carrier is capable of upward and downward motions only, and the rod to which it is attached passes through guides. The carrier is, moreover, supported by an ivory friction-wheel, *t*, which turns when the piece, *s*, revolves beneath it.

From this brief description, it is apparent that the cone, P, will always indicate the direction of the wind in azimuth, like ordinary vanes. At the same time the vertical component (if any) of the wind will raise or depress the tail, B. In the former case it is manifest that the wheel, *d*, will cause *e* to turn, so as to raise the rack, *f*, and in the latter case the effect will be to lower the rack. It follows, therefore, that the shaft, *c*, and consequently the pencil-carrier which it moves, must rise or fall according as the vertical motion of the air is upward or downward. A spring within the pencil-carrier constantly presses the pencil against a sheet of paper placed in front of it. This paper is for the present carried on a flat board, which is moved by a clock. The registering sheets are ruled with vertical hour lines and with horizontal lines which assist in estimating the angle of inclination to the horizon made by the disk during the action of an upward or downward impulse from the air. This follows because the tail and the wheel, *d*, revolve on the same centre, and each tooth in *d* describes an arc similar to that described by the axis of the tail. An equal number of teeth in *e* are raised or lowered, and thus the rack and the shaft, *c*, move through spaces proportional to arcs described by the teeth of the wheel, *d*, and the axis of the tail, B. The board

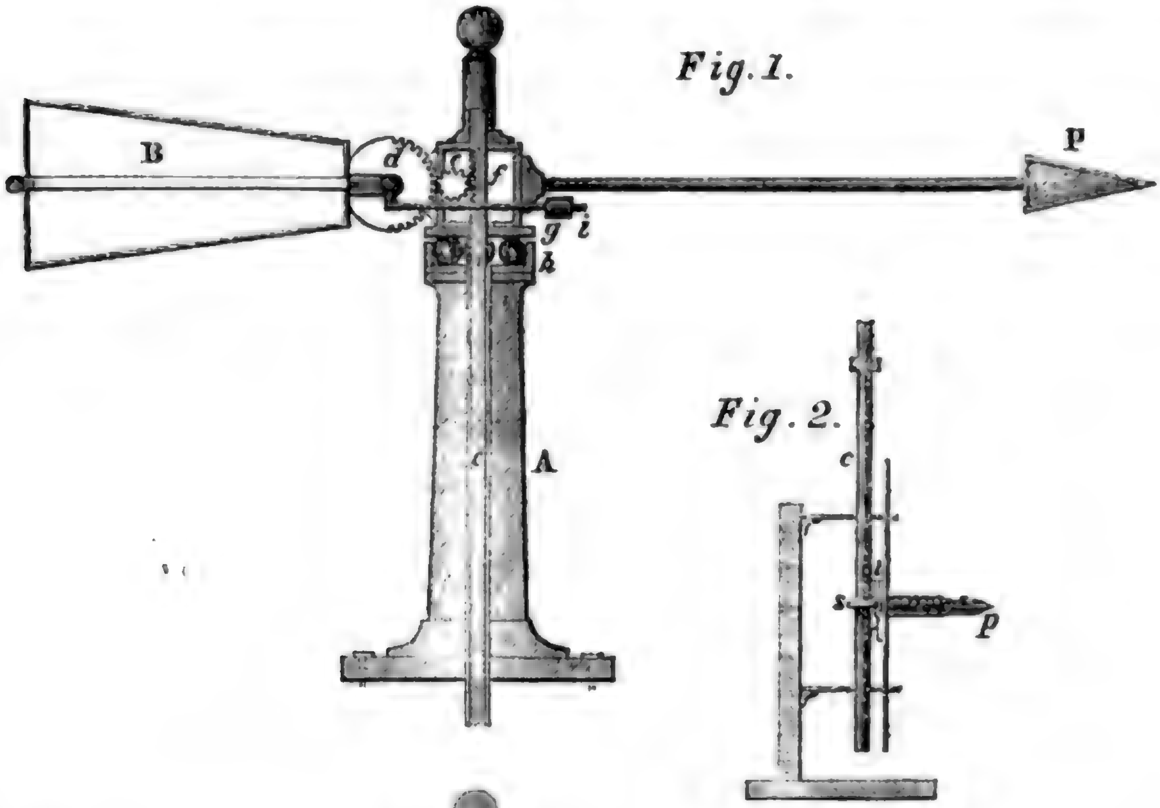

Fig. 1.

Fig. 2.

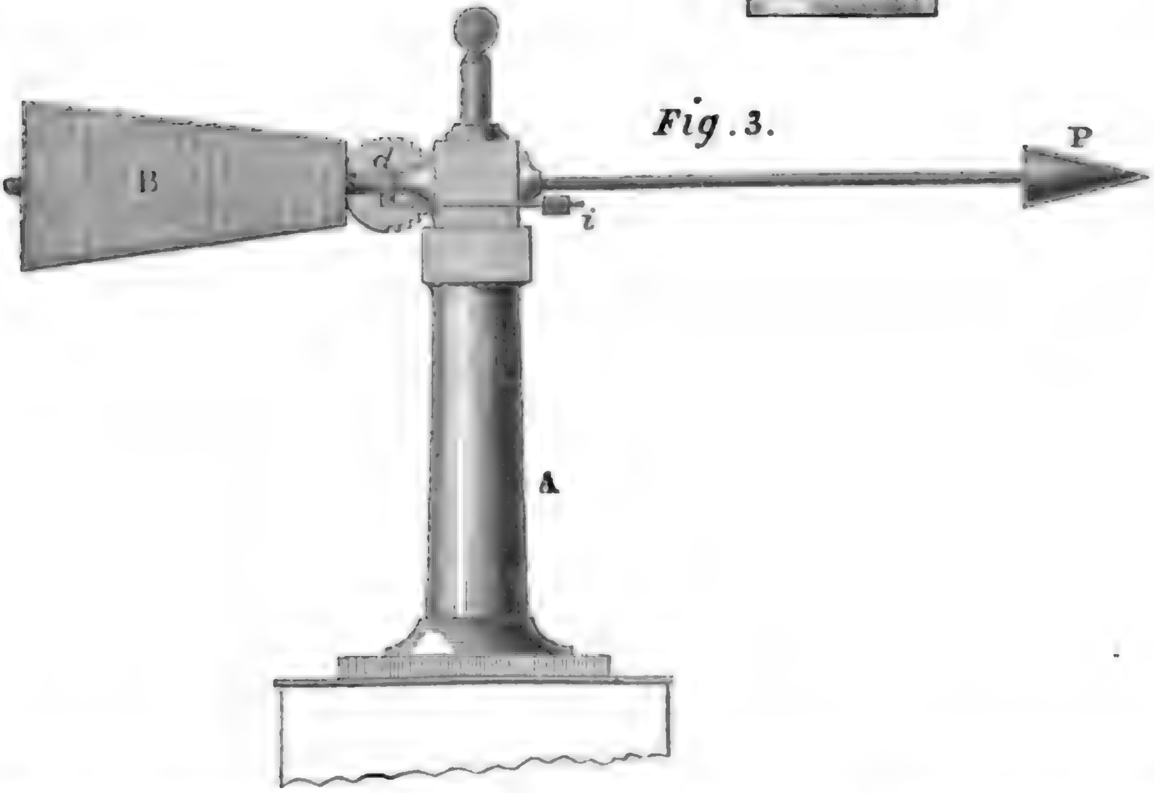

Fig. 3.

which carries the registering paper can be detached by loosening a clamping-screw which fastens it to the support turned by the clock, so that the sheets can be removed and replaced with speed and facility.

The entire apparatus was constructed by Mr. Spencer, of Aungier Street, Dublin; and he has executed the portion connected with the indication of horizontal movement in such a way, that the addition of a registering apparatus for this part of the instrument will not only be easy, but will render the entire combination a complete indicator of the absolute direction of the wind. The results of the instrument in its present state are exhibited on the registering sheets as nearly vertical pencil lines, some above and some below the neutral line, to which each sheet is carefully adjusted.

The anemoscope is at present so placed as not to be overtopped by any building; for it stands on the roof of one of the highest houses in Dublin, in a quarter remarkably open, and close to the south suburbs.

Owing to a variety of delays and obstacles in finishing the apparatus, it was not brought into action until the 31st of August, and thus I am able to report only on the results furnished by little more than the records of a single month. These records appear to indicate that vertical oscillations prevail more during the mid-day hours than at other periods; for although ten sheets show no definite predominance at any specific period of the day, and two predominance of vertical movements towards midnight, twenty-one show that these movements are most frequent at the hours about noon. From a journal of the weather which was kept at the same time, it appeared that on bright days, when the air had little horizontal motion, gentle upward movements prevailed at mid-day. Such phenomena are distinctly manifested by the sheets for September the 5th, 6th, 7th, 8th, and 9th, and all of these were bright sunny days. Before the 5th, the weather had been changeable and unsettled: but on comparing the two sheets comprehending from noon of the 3rd to noon of the 5th, I noticed that the amplitude of the oscillations of the anemoscope progressively and regularly diminished; and it occurred to me that this might indicate a tendency towards convective equilibrium of the atmosphere, and more settled weather. The weather continued fine until the 13th, when there was both high wind and rain, accompanied and preceded by energetic oscillations of the anemoscope. If the general circulation of the atmosphere takes place, as seems to be now completely established, by a twofold motion, one of translation, whether cyclonic or lineal, and the other undulatory, it follows that the pulsations of the latter movement may be influenced by aërial disturbances. The frequency, regularity, intensity, prevalent direction, and more or less intermittent character of these pulsations must depend on variations of pressure, density, moisture, and temperature, as well as on the rippling motion of the air. It is natural, therefore, to expect, what our limited number of observations seem already to indicate, namely, that the sudden and abrupt commencement of such pulsations is usually a precursor of other disturbances, while their gradual and regular diminution in energy would show a tendency in the air to approach a state of convective equilibrium, and might, therefore, be safely relied upon as a forerunner of fine weather. This point is illustrated by the remarks of the late Professor Daniell relative to the rapid oscillations of the water-barometer during high winds, and their gradual diminution preceding a return to a calmer state of the air*. Although the atmospheric pulse is undoubtedly compounded of the undulatory movements resulting from the flow of an elastic fluid over the irregularities of the earth's surface, with the effects of convection, in such a way as would render the separation of these effects extremely difficult, yet the careful study of this pulse in connexion with other phenomena may be reasonably expected to add to our power of forming correct conclusions regarding the coming changes of the weather.

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* Phil. Trans. 1832, p. 573.

Report of a Committee, consisting of the Rev. Dr. LLOYD, General SABINE, Mr. A. SMITH, Mr. G. JOHNSTONE STONEY, Mr. G. B. AIRY, Professor DONKIN, Professor WM. THOMSON, Mr. CAYLEY, *and the* Rev. Professor PRICE, *appointed to inquire into the adequacy of existing data for carrying into effect the suggestion of* GAUSS, *to apply his General Theory of Terrestrial Magnetism to the Magnetic Variations.*

IN order to explain the views of the Committee upon the question submitted to them, it is necessary to refer briefly to the leading points of Gauss's theory.

If $d\mu$ denote the quantity of free magnetism in any element of the earth's mass, and ρ the distance of that element from the point (x, y, z), and if we make

$$V = -\int \frac{d\mu}{\rho},$$

the partial differential coefficients of V with respect to the three coordinates, x, y, z, respectively, are equal to the components of the earth's magnetic force in the direction of the axes of coordinates. V is a function of x, y, and z, or of their equivalents u, λ, and r,—r being the distance of the point from the centre of the earth, and u and λ the angles corresponding to the north polar distance, and the longitude, on the sphere whose radius $= r$. This quantity may be expanded in a series proceeding according to the inverse powers of r, whose coefficients, P_1, P_2, P_3, &c., are functions of u and λ alone; and it is readily seen that, at the surface of the earth, the three components of the magnetic force are

$$X = -\left(\frac{dP_1}{du} + \frac{dP_2}{du} + \frac{dP_3}{du} + \text{\&c.}\right),$$

$$Y = -\frac{1}{\sin u}\left(\frac{dP_1}{d\lambda} + \frac{dP_2}{d\lambda} + \frac{dP_3}{d\lambda} + \text{\&c.}\right),$$

$$Z = 2P_1 + 3P_2 + 4P_3 + \text{\&c.},$$

and are therefore given when P_1, P_2, P_3, &c. are known.

The form of these functions is deduced from the well-known partial differential equation

$$n\,(n+1)\,P_n + \frac{d^2P_n}{du^2} + \cot u\,\frac{dP_n}{du} + \frac{1}{\sin^2 u}\,\frac{d^2P_n}{d\lambda^2} = 0,$$

n being the number indicating the order of the function. It is found that the first, P_1, contains three unknown coefficients; the second, P_2, five; the third, P_3, seven, &c. Hence, if the approximation be extended so as to include terms of the fourth order, there will be 24 coefficients to be determined. Each given value of X, Y, or Z, on the earth's surface, furnishes an equation among these unknown coefficients; and for each place at which the three elements are known we have three such equations. Hence to obtain the general expressions of X, Y, Z, to the fourth order inclusive, it is theoretically sufficient to know the three elements at eight points on the earth's surface. But, owing to the errors of observation, and to the influence of the terms neglected in the approximation, the number of determinations must, in practice, be much greater than the number of unknown coefficients.

The foregoing conclusions are based upon the hypotheses that magnetic attraction and repulsion vary according to the inverse square of the distance, and that the magnetic action of the globe is the resultant of the actions of all its parts. It is likewise assumed that there are two magnetic fluids in every magnetizable element, and that magnetization consists in their separation. But for these hypotheses we may substitute that of Ampère, which supposes the magnetic force to be due to electric currents circulating round the molecules of bodies.

This theory may be applied to the *changes* of terrestrial magnetism, whether regular or irregular, provided only that the causes of these changes act in the same manner as galvanic currents, or as separated magnetic fluids. We have only to consider whether the data which we possess are sufficient for such an application.

It has been already stated that, for the general determination of X, Y, and Z, we must know their values at eight points (at least) on the earth's surface, these points being as widely distributed as possible. The same thing holds with respect to the changes δX, δY, δZ; and to apply the formulæ so determined, and to compare them with observation, corresponding values must be known for (at least) one more point. In the case of the *irregular* changes these observations must, of course, be simultaneous. The *regular* changes must be inferred from observations extending over considerable periods; and there is reason to believe that these periods must be identical, or nearly so, for all the stations, since the changes are known to vary from month to month and from year to year.

The *regular* variations of the *three* elements X, Y, Z, or their theoretical equivalents, have been obtained by observation, for nearly the same period, at Greenwich, Dublin, and Makerstoun, in the British Islands; at Brussels and Munich, on the Continent of Europe; at Toronto and Philadelphia, in North America; at Simla, Madras, and Singapore, in India; and at St. Helena, the Cape of Good Hope, and Hobarton, in the southern hemisphere. Of these thirteen stations, however, the three British must be regarded, for the present purpose, as equivalent to one only, on account of their proximity; and the same thing may be said of the two North American stations and of the two stations in Hindostan. This reduces the number of available stations to *nine*, the minimum number required for the theoretical solution of the problem in the degree of approximation already referred to, and considered by Gauss to be necessary. It is true that we may add to these the stations at which *two* only of the three elements have been observed, viz. Prague and St. Petersburg, the three Russian stations in Siberia, and Bombay. But even with this addition, the number is probably insufficient for the satisfactory determination of the unknown coefficients; for it is to be remembered that the places, few as they are, are not distributed with any approach to uniformity, and that very large portions of the globe are wholly unrepresented by observations.

For the reason already stated, this defect in the existing data cannot be now repaired by supplemental observations at new stations, unless the series at all were so far extended as to embrace the whole period of the cyclical changes.

The simultaneous observation of the *irregular* changes is limited nearly to the same stations. In their case, too, there is the further imperfection, as respects the present problem, that the changes observed on "term-days" are for the most part inconsiderable, while those on days of great magnetic disturbance have seldom been observed continuously for any considerable time at all the stations.

For the foregoing reasons the Committee are of opinion that the data which we at present possess respecting the changes of terrestrial magnetism, whether regular or irregular, are not sufficient for the application of Gauss's theory, if, as above assumed, the approximation is to be extended so as to include terms of the fourth order (P_1 to P_4 inclusive). It is deserving of consideration, however, whether an inferior degree of approximation may not afford some valuable information. The affirmative side of this question has been so earnestly advocated by one of the members of the Committee, that it has been thought advisable to append his letter on the subject to this Report.

(Signed by order of the Committee) H. Lloyd.

Letter from Professor W. Thomson *to* Rev. Dr. Lloyd.

"Roshven, Strontian, Sept. 24, 1862.

"My dear Sir,—I am sorry to have been so long prevented from writing to you on the subject of the Committee's Report on the expression of the Variations of the Terrestrial Magnetic elements in series of Laplace's functions.

"I perfectly agree with the conclusions stated in the draft report of which you sent me a proof, so far as they relate to a complete expression of any class of variations of the elements, or of any individual variation, by means of which its amount in other localities than those of observation could be determined with any considerable approach to accuracy. But, on the other hand, the amount of knowledge from observation, shown in the report to be available, would, I believe, be sufficient to allow us to estimate, possibly with considerable accuracy, and certainly with a sufficient approach to accuracy for highly important application, the first terms in the harmonic (Laplace's) series. I would therefore advise that some such method as the following should be adopted.

"Choosing any particular variation, for instance the diurnal or the secular, for which the data from observation are most abundant, find either by trial and error, or any other proper algebraic method, an expression by terms of the first order (three coefficients for each) for the three elements which most nearly represent it. (The method of least squares would give a precise definition of what would be the most near representation, on this principle; but ruder and quicker methods might suffice in first trials.) Then, judging by the results, try similarly for expressions in series of two terms ($3+5$, or eight coefficients in all, in each expression). After trials of this kind it would be easy to judge within what limits may be the probable errors of the estimated first terms from the true first terms, and possibly even to arrive at some probable knowledge regarding the true second terms of the harmonic expressions.

"A very moderate degree of success in such operations as these would allow us to decide whether the origin (magnetic or electrodynamic) of the variation is within the earth's surface or outside, "I hope, then, a result of the Committee's action may be to carry out an attempt of this kind for every class of variations for which the data give even the narrowest foundation. It might be applied, I believe, with success, as regards the main conclusion, to every case in which each of the three components has been well determined for even only THREE stations widely apart from one another.

"It seems probable that an individual deflection of a magnetic storm cannot be identified in localities at very great distances from one another. This must certainly be the case if an individual deflection, and individual flash or flicker of aurora, are simply related to one another, because the individual auroras are certainly local in the sense of being only seen at once over a very limited area of the earth, being in fact actually situated at some distance of not more than 150 miles (which I believe is the highest estimate) from the surface. Hence it is probable that it will be found whether the seat of the disturbing action, producing an individual deflection in a magnetic storm, is above or below the surface, by comparing observations made at stations within a few hundred miles of one another, and endeavouring to identify a single disturbance in the three components at all the localities. If the three components could thus be determined at three localities so wide apart as to show considerable differences in the amounts, but yet not so wide as to render the identification of the disturbance difficult, the question whether the seat of the disturbance is in the earth or the air would be answered with high probability.

"I remain, yours very truly,

(Signed) "WILLIAM THOMSON."

On Thermo-electric Currents in Circuits of one Metal.
By FLEEMING JENKIN, *Esq.*

LAST year I had the honour of directing the attention of the Association to the fact, that an electric current of considerable intensity may be obtained in a circuit of one metal by the application of heat to one or the other side of an interruption in the wire composing the circuit. The experiment is most simply performed by looping together the two ends of two perfectly similar wires connected to the terminals of a galvanometer, and heating one of the loops to a white or red heat in a spirit-lamp, or Bunsen's burner. If the one loop rests very lightly on the other a current will be obtained, which in the copper wires will flow from the hot to the cold loop across the joint with sufficient intensity to deflect a moderately sensitive galvanometer, even with a resistance in circuit equal to 1000 miles of No. 16 copper wire.

The electromotive force of the combination is about one-tenth that of a Daniell's cell. With two *iron* loops a permanent current in the opposite direction is obtained, flowing from cold to hot across the joint, but the electromotive force in this case is very much smaller.

When the loops are drawn tightly together the current ceases, but reappears as soon as the strain is slackened.

I was at the time unable to show the connexion between these singular currents and other electrical phenomena, but I am now, in consequence of further experiments undertaken for the Association, able to point out that connexion.

The currents were clearly not due to chemical action on the wires; for, in the first place, currents of considerable strength were obtained from two perfectly homogeneous platinum wires, flowing from hot to cold across the loose contact; and in the second place, the direction of the current was different in copper and iron, whereas the chemical action undergone by the wire was alike in the two cases.

The researches of Becquerel, Pouillet, Buff, Hankel, and Grove were examined, to see whether the electricity produced during combustion, or the properties of flame, would account for the currents, but it was found that all the electrical effects produced by flame could be divided into two classes: first, phenomena depending on the relative position of the two wires in the flame; and secondly, phenomena depending on the voltaic couple formed by the metals used, and the hot vapour acting as an electrolyte between them. My results were independent of the position of the wires in the flame, and could not be accounted for by supposing these wires to form a voltaic couple, inasmuch as though in some cases, where wires of two metals were looped together as described, the current flowed from the metal most attacked across the imaginary electrolyte to the other wire, in other cases it flowed in the opposite direction.

It remained to be seen whether the currents might not have a thermoelectric origin. Last year I imagined that the effect observed might be directly due to discontinuity, but that idea was dispelled by some experiments with loose contacts between wires of different metals, which have thrown great light on the question.

Loops of iron, silver, platinum, gold, and copper wires were combined two by two in all the possible arrangements, and the currents measured which were obtained when one or the other or both loops were heated with loose and tight contacts between them.

A Table was thus formed, which is appended to the present paper.

The resistance of the circuit was so large (2050×10^4, Weber's absolute $\frac{\text{foot}}{\text{seconds}}$) that the inherent resistance of the joint and of the different short wires used in each experiment could be neglected, and the deflections obtained on a reflecting galvanometer could be taken as approximatively proportional to the electromotive force of each combination. The common thermo-electric currents produced by the metallic contact between dissimilar wires almost vanish in comparison with those produced by the loose contacts.

I need not present a complete analysis of the Table, but will speak only of the combination of iron and copper with which the most remarkable results were obtained. When the usual tight metallic contact was made between these two wires and the two loops equally heated, the current first flowed from copper to iron across the joint, and then as the temperature rose ceased altogether, and finally, at a red or white heat, flowed from iron to copper. The maximum deflection obtained in either direction was three divisions. These deflections showed the celebrated inversion discovered by Cumming.

If the pressure between the loops was relaxed, the current ceased altogether; but when the loops were moved, so that the copper became red-hot while the iron was cool, a current flowed from the copper to the iron, or from hot to cold across the joint, giving a deflection of 100 divisions; whereas if the iron was heated red-hot and the copper cooled, a current giving 90 divisions flowed in the opposite direction, or from iron to copper, but from hot to cold as before. Thus in these two cases the loose-contact currents given when one or the other loop was heated, flowed in the opposite direction between the metals, but in both cases from hot to cold across the joint, and were in each case about thirty times as great as the currents given by the thermo-electric difference between the metals.

It was found on examining the Table, that wherever copper appeared in conjunction with any other of the metals named, the direction of the loose-contact current could invariably be determined by the following rule:—When the copper was the hot wire, the current flowed from the copper to the other metal across the joint; but when copper was the cold metal, the current flowed from the other metal to the copper, or in both cases from hot to cold.

Exactly the contrary was found wherever iron appeared in conjunction with any of the five metals but copper; the current then always flowed from cold to hot. Two copper wires alone gave the largest deflection, of about 220 divisions; and two iron wires alone gave the next largest of those obtained where single metals only were used, but of course in the opposite direction to the deflection from copper.

It was then perceived that all these results would be explained if the thin coating of oxide on the copper wire might be regarded as a conductor with a hot and cold junction, and endowed with thermo-electric properties far more positive than the iron, while at the same time the coating of oxide on the iron wire would have to be regarded as far more negative than the copper. It was, however, difficult to suppose that two bodies so similar in some respects as the oxides of copper and iron should be at opposite extremities of the thermo-electric scale, but the following direct experiment left no doubt on my mind.

A little spiral was made of platinum wire, and a small quantity of oxide of copper laid upon it, and held in a flame till white-hot; another platinum wire was then dipped in the melted mass, when a strong current was at once observed from the hot to the cold wire, as if a loose contact had been made between two copper wires. When either of the oxides of iron was tested in a similar manner, a strong current was obtained from the cold to the hot platinum wire, as if a loose contact had been made between two iron wires.

I do not yet know positively what the substances are which, interposed between silver and platinum and gold wires, give rise to the loose-contact currents, but I feel no doubt that these are as much thermo-electric currents as those given by the oxides of copper and iron, and are produced in a circuit composed of the metal and a very thin hot film, of which the two surfaces are unequally heated.

There are, however, some good reasons for doubting whether electrolytes can be included in a true thermo-electric series, and I consulted many authorities with reference to this point. Seebeck himself includes many electrolytes in his thermo-electric scale, and places acids below bismuth, a result confirmed lately by Gore (in 1857); he also places certain salts above antimony, a result subsequently confirmed by Andrews of Belfast in 1837. This gentleman observed that the tension produced by the salts between the wires was about equal to that between a platinum and silver plate in dilute sulphuric acid, and that the metals used as electrodes did not influence the deflection. He considered the current certainly due to a thermo-electric action.

Faraday in 1833 discovered what Becquerel subsequently called pyro-electric currents; the currents were in different directions with different substances used, and some, if not all, were of the same nature as those I have described. Leroux and Buff obtained currents where glass acted as the electrolyte. Leroux considered them thermo-electric, and Buff chemical effects. Buff also attributes some of the electrical phenomena connected with flame to a thermo-electric action in which unequally heated air or gas forms part of the circuit. The currents obtained when a hot and cold platinum wire are dipped into dilute sulphuric acid and other liquids are well known; and finally (in 1858), Mr. Wild published a laborious research, in which he seems to prove the development of thermo-electric currents not only at the junction between metals and various solutions, but also between two different solutions. Thus, although none of the above observers seem to have tested the oxides, there seems little reason to doubt that they may be classed with other electrolytes, and may give rise to currents in the same manner. On the other hand, I cannot yet consider it definitively proved that any of the currents obtained from electrolytes are due to a true thermo-electric action—that is to say, to an absorption of heat only, especially as Mr. Wild could find no trace of the Peltier heating and cooling effect at the junctions of his solutions. Further research, showing the source of the power developed, is most desirable.

While consulting the literature connected with this subject, I found that Gaugain had to some extent preceded me in the discovery of the loose-contact currents, in a paper published in the 'Comptes Rendus' in 1853. He comes to the same conclusion as I had done independently, that they were due to the unequally heated film of foreign matter, and places oxide of iron below platinum, and oxide of copper above gold and zinc, but below iron, instead of very much above it as I find. He does not appear to have observed the exceedingly high electromotive force to be obtained from these bodies, no doubt owing to the use of a short galvanometer coil of thick wires, such as is commonly used for thermo-electric researches. He introduces a carburet of iron, of which I find no trace, with more positive properties than oxide of copper, to explain some of his results. He gives very few data on which to found his theory, but simply mentions his conclusions, and appears to have made no direct experiment whatever with the oxides. Owing to these circumstances his experiments seem to have attracted little attention. I have endeavoured to contrive a convenient apparatus by which to study the properties of the oxides, but have not hitherto met with much success, owing to the great difficulty in maintaining a constant difference of temperature between the surfaces of the very thin film, which can alone be used with success. Next year I hope to obtain further results in elucidation of these quasi thermo-electric currents from electrolytes.

I now wish to add a few remarks on the currents which occur when true metallic contact is made between a hot and cold end of a wire of one metal. The existence of these currents was placed beyond all doubt by Magnus's careful experiments, but their connexion with other thermo-electric phenomena has hitherto remained entirely without explanation. Wild has suggested that they might be due to a thermo-electric couple formed with hot air or gas at the moment of junction; but experiments which I have made show this explanation to be founded on a mistaken conception of the duration of the current, which is by no means instantaneous, but lasts at least five minutes with copper or with iron wires, very gradually decreasing in intensity from a maximum to zero.

Another explanation, viz. that the deflection is due to a sort of discharge of a statical effect produced by the unequal distribution of heat, is also negatived by the same consideration, as well as by the fact that a tension of sufficient magnitude to produce such a charge could not possibly have escaped observation by direct measurement.

Professor W. Thomson has shown conclusively, in his 'Dynamic Theory of

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loops of one and two metals.

deviations observed on a reflecting galvanometer, and are very

COLD METALS ON LEFT.

GOLD.	COPPER.
Heated at right side. contact → 15 contact → 2 *Heated in middle.* ximum ← 4 (hotter) → 4	*Heated at right side.* Loose contact ← 100 Tight contact → weak *Heated in middle.* 1st maximum ← 3 2nd do. (hotter) → 3
Heated at right side. contact ← 10 contact ← weak *Heated in middle.* um ← 1	*Heated at right side.* Loose contact ← 190 Tight contact ← 2 *Heated in middle* Maximum ← 2
Heated at right side. contact → 10 contact → 10 *Heated in middle.* um → 10	*Heated at right side.* Loose contact ← 80 Tight contact → 10 *Heated in middle.* Maximum → 15
Heated at right side. contact ← weak contact → weak *Heated in middle.* um 0	*Heated at right side.* Loose contact ← 170 Tight contact ← weak *Heated in middle.* Maximum → weak
Heated at right side. contact ← 280 to 300 contact ← weak *Heated in middle.* um ← weak	*Heated at right side.* Loose contact ← 220 Tight contact ← weak *Heated in middle.* Maximum 0

Heat,' that if the condition of metal at a certain temperature depended exclusively on that temperature, no distribution or movement of heat could possibly give rise to a current of electricity in a circuit of one metal; nevertheless I find, as above stated, that in a circuit of one metal wire a current is maintained for five minutes at a time, gradually vanishing to nothing when the two ends of the homogeneous wire have been for some time in contact, but recommencing if one wire is cooled for a minute and then again applied to the hot one. One explanation of this might be that the condition of the wires does not solely depend on their temperature, but is influenced to a considerable extent by the time during which they have remained at that temperature. Nor is this a gratuitous assumption: Dr. Matthiessen has proved that wires of several metals do not attain a constant *conducting* power until they have been kept for some time at a constant temperature; he finds that the conducting power of bismuth increases, while that of tellurium decreases when kept for a time at 100°. Quite similarly, some metals may rise and some may fall in the thermo-electric scale after being heated for some time, a supposition which is necessary to account for the metallic contact currents by the theory I suggest.

Another possible explanation of the metallic contact currents may be found in a partial hardening on the one side and annealing on the other, caused by the sudden contact of the hot and cold metal. If this be so, the current between annealed and unannealed wires of the same metal would correspond with the contact current between two homogeneous wires, in a way which it does not seem to do.

I am, however, now engaged in investigating this subject, and hope before next year to be able to give facts which may decide whether either of these theories is tenable. There is great difficulty in forming any conclusion from experiments hitherto made, inasmuch as none of the observers, except Dr. Matthiessen, have used chemically pure metal, and it is found that the electrical properties of a metal are affected to an extraordinary degree by the presence of impurities in very small quantities.

Explanation of the Table.

The names of the metals of which the loops were made are entered at the side and top of the Table. The experiments made with each combination are entered in the subdivision at the intersection of the horizontal and vertical columns corresponding to the two metals. The metals named at the top formed the right-hand loop, those at the side the left-hand loop. The arrows show the direction of the current *across the joint*. The first entry in each subdivision shows the deflection observed when the right-hand metal was heated and the wires held loosely together. The second entry shows the deflection when the same metal was heated but the wires drawn tightly together.

The third entry gives the maximum deflection, and the direction of the current, when the middle of the joint is gradually heated and the two wires held tightly together.

The fourth entry (where given) shows the maximum deflection from a current in the opposite direction when greater heat was applied. The two last entries show the common well-known metallic thermo-electric effects. The first entry shows the new loose-contact effect. The second entry shows an uncertain combined effect of metallic and imperfect contact effects.

An example will perhaps make this clearer. When copper and iron were used and copper loop heated, a loose contact produced a current from copper to iron across the joint, giving a deflection of 100 divisions. A tight contact gave nothing decided. When the iron loop was heated (the copper cold) the loose contact produced a current from iron to copper across the joint, giving a deflection of 90 divisions. A tight contact in this case gave a weak current in the opposite direction. When the joint was heated in the middle, as the temperature gradually rose, a maximum deflection of 3 divisions was first reached, showing a current from copper to iron across the joint; and as the heat increased still further this current was reversed, and finally, at a white heat, gave a maximum deflection of 3 divisions with a current from iron to copper.

On the Mechanical Properties of Iron Projectiles at High Velocities.
By W. FAIRBAIRN, *F.R.S.*

A VALUABLE series of experiments were made at Manchester upon portions of plates fired at by the Iron Plate Committee at Shoeburyness. These experiments comprised the determination of the resistance to punching, to a tensile strain, to impact, and to pressure.

They show that the tenacity varied from 11 to 29 tons per square inch in the iron plates, and from 26 to 33½ tons in the homogeneous iron plates. The average strength of the iron plates between 1½ and 3 inches thick varied from 23½ to 24½ tons per square inch, and this, or about 21 tons, may probably be insisted upon as a measure of strength in future contracts for iron plates.

The elongation of the plates under a tensile strain may be taken as a measure of the ductility of the material; it varied in the thicker iron plates from 0·91 to 0·27 per unit of length, and averaged 0·27 inch in the homogeneous metal plates. The maximum observed was 0·35.

The most important results in connexion with the question of the resistance are, however, those obtained by combining the tensile breaking weight with the ultimate elongation, as first indicated by Mr. Mallet in a paper read before the Institution of Civil Engineers. By finding in this manner the product of the tenacity and ductility, numbers are obtained which, though not identical with those expressing the resistance of the plates in the experiments with guns at Shoeburyness, are yet in close correspondence with them. The average value for Mr. Mallet's coefficient in the thicker iron plates was about 6500 lbs., and in the steel or homogeneous plates 8300 lbs. But the resistance of the iron plates increases with the thickness, whilst that of the homogeneous metal diminishes. The correspondence of these numbers is indicated in the Report addressed to the War Office and the Admiralty; but a more extended series of experiments are yet wanting to determine the true value of the coefficient as a guide to be insisted upon in the manufacture of iron plates. 9000 foot-pounds is the maximum for iron given by the results already obtained; but an extended series of experiments might develope new features of resistance and new improvements in the manufacture.

The experiments on punching afford an explanation of the greatly increased perforating power of the flat-headed shot over that of the round-headed projectiles. They also lead to a formula for the ordinary cast-iron service shot, which appears to give with approximate accuracy the law of the resistance of plates of different thicknesses to missiles of various weights and velocities.

These investigations led to inquiries into the state of the manufacture of plates calculated to resist heavy and powerful projectiles directed against the sides of an iron-plated ship, and, moreover, to determine the exact thickness of plates that a vessel was able to carry. Again, they had reference to the quality of the plates and their powers of resistance to impact. There were three conditions necessary to be observed in the manufacture: 1st, that the material should be soft and ductile; 2nd, that it should be of great tenacity; and, lastly, that it should be fibrous and tough. All these conditions apply to the manufacture of plates, and they also apply, with equal force, to the projectiles in their resistance to pressure and impact.

In the experiments at Shoeburyness, it was found that the ordinary cast-iron service shot were not adapted for penetration, as they invariably broke into fragments when discharged against a sufficiently thick armour-plate. In most cases when delivered at high velocities, they had the power of damaging and breaking the plates; but owing to their crystalline character and defective tenacity, a considerable portion of the power was expended in their own destruction. To some extent the same law was applicable to wrought-iron shot, as part of the force, from its greater ductility, was employed in distorting its form, and depriving it of its powers to penetrate the plate. Cast and wrought iron are therefore inferior as a material for projectiles intended to be employed against iron-plated ships and forts. With steel hardened at the end the case is widely different, as its tenacity is not only much greater than that of cast and wrought iron, but the process of hardening the head prevents compression and its breaking up by the blow when the whole of its force is delivered upon the plate. Steel, although much superior to cast or wrought iron in its power of resistance in the shape of shot, is, nevertheless, susceptible of distortion and compression, and in every instance when employed against powerful resisting targets the compression, and consequently the distortion, was distinctly visible.

There is another consideration besides the material which enters largely into the question of the resisting powers of shot, and that is *form*. It will be recollected that, some years since, the late Professor Hodgkinson instituted a series of experiments to determine the strength of iron pillars, and the results obtained were in the following ratios:—

	lbs.
1st. That pillars of about 20 to 30 diameters in length, with two flat ends, broke with........................	3000
2nd. Pillars with one end rounded and one flat broke with	2000
And 3rd. Pillars with both ends rounded broke with......	1000

being in the ratio of 1, 2, 3. Now in order to ascertain the effects of form on cylindrical shot, a series of experiments were instituted to determine the force of impact and statical pressure produced upon shot of different shapes, and from these experiments the following results were obtained.

The description of shot experimented upon was cast-iron of the cylindrical form, with flat and round ends; and it is interesting to observe that the results correspond with those where both ends are rounded and one end only rounded, as obtained by Mr. Hodgkinson on long columns; but in the short specimens with both ends rounded the results are widely different, as may be seen by the following Table.

No. of Experiments.	Crushing weight in lbs.	Ultimate compression in inches.	Pressure per square inch in lbs.	Pressure per square inch in tons.	Remarks.
1.	73,428	·120	122,115	54·51	Both ends flat.
2.	68,062	·092	125,787	55·13	
Mean	......	......	123,951	54·82	Areas ·5674 and ·7088.
3.	35,540	·22	62,636	27·96	One end rounded.
4.	40,916	·24	57,725	25·77	
Mean	......	......	60,180	26·86	Areas ·7088 and ·7088.
5.	38,260	·25	53,978	24·09	Both ends rounded.
6.	37,580	·25	53,030	23·67	
Mean	37,920	·25	53,504	23·88	Areas ·7088 and ·7088.

From the above experiments, it is evident that the round-ended shot loses more than one-half its power of resistance to pressure in the direction of its length; and this may be accounted for by the hemispherical end concentrating the force on a single point, which, acting through the axis of the cylinder, splits off the sides by a given law of cleavage in every direction. On the other hand, the flat-ended specimens have the support of the whole base in a vertical direction; and from these we derive the following comparative results:—

Taking the resistance of the flat-ended shot at 54·82 tons per square inch, and that with hemispherical ends at 26·86, we have a reduction from the mean of the flat-ended columns of 27·96 tons, being in the ratio of 100 : 49; or, in other words, a flat-ended shot will require more than double the force to crush it than one with one of its ends rounded. Now, as the same results were obtained at Shoeburyness, in the appearance of the fractured ends, when similar shot was fired from a gun, we arrive at the conclusion that the same law is in operation whether rupture is produced by impact or statical pressure.

In the experiments on cast-iron shot, the mean compression per unit of length of the flat-ended specimen was ·0665, and of the round-ended ·1305. The ratio of the compression of the round- to the flat-ended was therefore as 1·96 : 1, or nearly in the inverse ratio of the statical crushing pressure. It has been correctly stated that it requires a considerable amount of force to break up shot when delivered with great velocity against an unyielding object, such as the side of an iron-cased ship, or a target representing a portion of that structure; and it may be thence inferred that the force expended in thus breaking up the shot must be deducted from that employed in doing work on the plate. This is confirmed by experiment, which shows that though the whole of the force contained in the ball, when discharged from a gun at a given velocity, must be delivered upon the target, the amount of work done, or damage done to the plate, will depend on the weight and the tenacity of the material of which the shot is composed.

If, for example, we take two balls of the same weight, one of cast iron and the other of wrought iron, and deliver each of them with the same velocity upon the target, it is obvious that both balls carry with them the same projectile force as if they were composed of identically the same material. The dynamic effect or work done is, however, widely different in the two cases, the one being brittle and the other tough: the result will be, that the cast iron is broken to pieces by the blow, whilst the other either penetrates the plate or, what is more probable, flattens its surface into a greatly increased area, and

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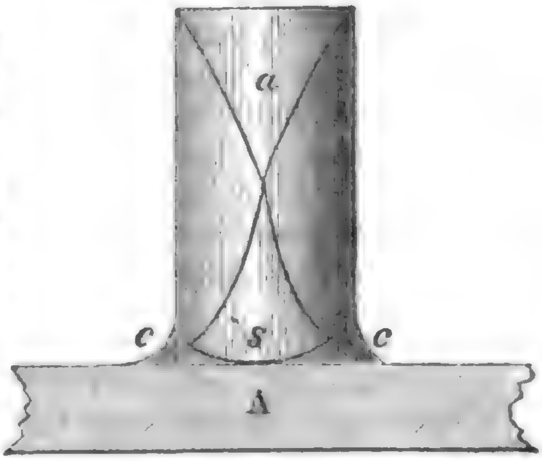
inflicts greatly increased punishment upon it. In this instance the amount of work done is in favour of the wrought iron: but this does not alter the condition in which the force was first delivered upon the target; on the contrary, it is entirely due to the superior tenacity of wrought iron to that of cast iron, which yields to the blow, and is broken to pieces in consequence of its inferior powers of resistance. The same may be said of steel in a much higher degree, which delivers nearly the whole of its *vis viva* upon the plate.

In the foregoing experiments it will be observed that the resistance of cast-iron flat-ended shot to a crushing force is about 55 tons per square inch, whilst in the two following we find that the round-ended specimens, of the same material, gave way and were crushed with a pressure of only 26½ tons—rather less than one-half the force required to crush the flat-ended ones. It is a curious but interesting fact (provided the same law governs the force of impact as dead pressure) that the round-ended projectile which strikes the target should lose, from shape alone, one-half its powers of resistance. This may be accounted for as under.

Take, for example, a cylinder of cast iron, *a*, with a rounded end forcibly pressed against the steel plate A, until it is crushed by a fixed law of fracture observable in every description of crystalline structure; that is, the rounded end or part *s* forms itself into a cone, which, acting as a wedge, splits off the sides *c c* in every direction at the angle of least resistance, and these, sliding along the sides of the cone, are broken to pieces on the surface of the plate.



At Shoeburyness the same results were observable in all the experiments with spherical and round-ended shot, each of them following precisely the same law. In every case where the shot was broken to pieces, the fractured parts took the same direction, forming a cone or central core similar to that shown at *s*, as exhibited in my own experiments on statical pressure with the round-ended cylindrical shot.

The law of fracture of cast iron has been carefully investigated by the late Professor Hodgkinson in his paper on the strength of pillars, to which we have referred. It is there clearly shown that the resistance of columns when broken by compression is in the ratio of 1, 2, and 3; the middle one, with only one end rounded, being an arithmetical mean between the other two. Now these important facts, according to all appearance, bear directly upon the forms necessary to be observed in the manufacture of projectiles, as we find cylindrical shot with round ends loses one-half its powers of resistance to a pressure or a blow which tends to rupture or to break it in pieces.

My own experiments given above do not exactly agree with those of Professor Hodgkinson—the ratio of resistance in a column with one end rounded, and that of a column with both ends flat, being as 3 : 1·5, instead of as 3 : 2 as in his experiments,—a discovery probably explained by considering that he employed cast-iron pillars from 20 to 30 diameters in length, whereas my own were only two diameters long. Professor Hodgkinson has, indeed, expressed an opinion that the difference of the strengths of the three forms of pillars becomes less according as the number of times the length of the pillar exceeds the diameter decreases, which is the reverse of the results obtained in the foregoing experiments. But on this I may observe, that the conclusion is founded on a very limited number of experiments on wrought-iron columns of 15 to 30 diameters long as compared with others of 60 diameters, which, in my opinion, has been prematurely assumed as a general law. With wrought iron especially, the crushing-up of the rounded ends would soon bring pillars of that form into the condition of flat-ended pillars when the breaking weight approached the ultimate strength of the material—a conclusion confirmed by observing that the experiments in question are exactly those in Mr. Hodgkinson's table in which the breaking weights of the pillars are greatest. However this may be, the experiments I have given show that short cylinders with flat ends have twice the strength of similar cylinders with *one end rounded*. From this it would appear that the law for short cylinders is not the same, but altogether different from that obtained by Mr. Hodgkinson for long cylinders.

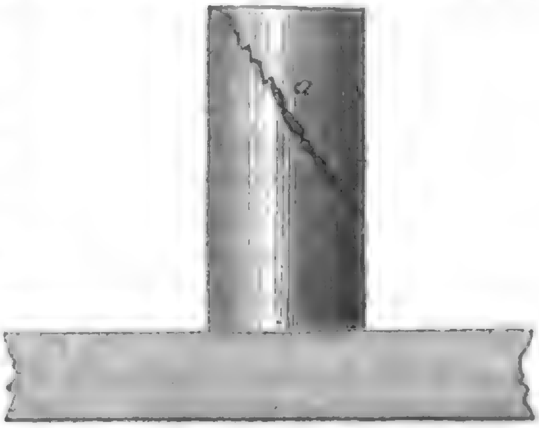
The discrepancies which appeared to exist between my own experiments and those of Professor Hodgkinson induced me still further to inquire into the law which seems to govern short bolts of columns of two diameters in length. To account for those discrepancies, the experiments were extended to columns with both ends rounded; and what renders them interesting is, that in short columns with both ends rounded the powers of resistance are nearly the same as those with one end flat and one end rounded, and moreover they appear to follow a different law from that of Professor Hodgkinson's long columns, which, in most cases, broke by flexure.

The difference in strength between short columns with both ends rounded and those with one end flat and one end rounded is almost inappreciable, as will be seen by comparing their values as under:—

	Tons per square inch.
Columns of two diameters long with flat ends crushed with	54·82
Columns with one end rounded and one flat „ „	26·86
Columns with both ends rounded .... „ „	23·88

So that the difference between them may be taken as the numbers 55, 27, and 24, or, in other words, in the ratio of 1 : ·49 with one end rounded and one end flat—that with both ends flat representing unity—and as 1 : ·44 with both ends rounded; a comparatively slight difference between those with one end flat and the others with both ends rounded.

With regard to the dynamic effect, or work done, by round-ended shot as compared with flat-ended ones, it has already been shown that with dead pressure the indentations produced on wrought-iron plates by a round-ended shot are nearly 3½ times greater than by those with the flat ends, and that the work done is twice as great in the case of the round ends as compared with that by the flat ends. This may be accounted for by rounded shot striking the plate with its pointed end, and the force of the blow being given by a comparatively small area; the *vis viva* or the whole force is thus concentrated and driven into the target to a depth considerably greater than if spread over the whole area of the projectile. The flat-ended cylindrical shot, which indicates such powerful resistance to pressure, is generally fractured by one or more of its sides being forced downwards in the direction of the line *a*, and hence its superior resistance when the whole area of the cylinder forms the base as the means of support.



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The difference of form does not, however, lessen the quantity of mechanical force (the weights being the same), as each ball has the same work stored in it when delivered from the gun at the same velocity, and the blow upon the target ought to be the same in effect but for the difference of shape in the case of the round ends, which break to pieces with one-half the pressure.

It is difficult to estimate the difference of force or work done upon the target by the two balls; it is certainly not in the ratio of their relative tenacities (the metal being the same), but arising from form, as the one would strike the target with its whole sectional area in the shape of a punch adapted for perforation, whilst the other, although much easier fractured, would effect a deeper indentation upon the plate.

The same law of defective resistance is observable in wrought iron and steel as is indicated in cast iron, but not to the same extent. On comparing the mean of twenty-six experiments on wrought iron with those on cast iron, it is evident that the difference between the two is considerable in their respective powers of resistance to compression. In the experiments on cast iron the specimens were invariably broken into fragments, and those of wrought iron, although severely crushed, were not destroyed. The same law, however, appears to be in operation in regard to the flat- and the round-ended specimens, although less in that of wrought iron, as both forms were squeezed so as to be no longer useful, the ratios being as 75 : 50 nearly, or 100 : 67·4. The round-ended shot, as might be expected, supported considerably more than one-half the pressure applied to the flat-ended one before it was finally distorted, whilst the cast iron was broken with less than one-half the pressure required to crush the flat-ended specimens. From these and the experiments on impact, there cannot exist a doubt as to the damaging effects of wrought-iron projectiles.

The experiments on steel indicate similar results to those on cast and wrought iron, as may be seen from the mean of nineteen experiments given in the following summary of results:—

No. of Experiments.	Breaking weight in lbs.	Ultimate compression in inches.	Pressure per square inch in lbs.	Pressure per square inch in tons.	Remarks.
9	145,756	·04	269,419	120·27	Flat-ended.
10	114,980	·21	202,643	90·46	Round-ended.

Here the same law of defective resistance is present in the round-ended cylinders as in those of cast iron, and doubtless the same ratio would have been obtained, provided the apparatus had been sufficiently powerful to have fractured the flat-ended specimens; we may therefore conclude that, instead of the above ratio of 100 : 75, it would have been 100 : 50 or thereabouts. From these facts, and those on wrought iron, we are led to the conclusion that the power of resistance to fracture of a cylindrical shot with both ends flat is to that with its front end rounded as 2 : 1 nearly.

The experiments of which the above is an abstract were extended to lead, as well as cast and wrought iron, and steel; but those on lead were of little value, as the compression was the same whether the ends were rounded or flat. This is accounted for by the extreme ductility of the metal and the facility with which it is compressed. As regards the wrought-iron specimens it may be observed that no definite results were arrived at, excepting the enormous statical pressure they sustained, equivalent to 78 tons per square inch of sectional area, and the large permanent set which they exhibit. These comparative values are as follows:—

	Statical resistance in tons per square inch.	Dynamical resistance in foot-pounds per square inch.
Cast iron, flat ends	=55·32	776·8
Cast iron, round ends	=26·87	821·9
Steel, round ends	=90·46	2515·0

From the experiments on the wrought iron, the flat-ended steel specimens, and the lead, no definite conclusion was arrived at, the material being more or less compressed without the appearance of fracture. The mean resistance of the cast iron is 800 foot-pounds per square inch, whilst that of steel is 2515 foot-pounds, or more than *three times* as much. The conditions which appear to be derivable from these facts, in order that the greatest amount of force may be expended on the iron plate, are therefore:—Very high statical resistance to rupture by compression. In this respect wrought iron and steel are both superior to cast iron; in fact, the statical resistance of steel is more than three times that of cast iron, and more than two and a half times that of wrought iron. Lead is inferior to all the other materials experimented upon in this respect. Again, resistance to change of form under severe pressure and impact is an important element in the material of shot. In this respect hardened steel is infinitely superior to wrought iron. Cast iron is inferior to both. In fact, the shot which would produce the greatest damage on armour-plates would be one of adamant, incapable of change of form, and perfect in its powers of resistance to impact. Such a shot would yield up the whole of its *vis viva* on the plate struck, and, so far as experiment yet proves, those projectiles which approach nearest to that condition are the most effective.

Report on the Progress of the Solution of certain Special Problems of Dynamics. By A. CAYLEY, *F.R.S., Correspondent of the Institute.*

MY "Report on the Recent Progress of Theoretical Dynamics" was published in the Report of the British Association for the year 1857. The present Report (which is in some measure supplemental thereto) relates to the *Special Problems* of Dynamics: to give a general idea of the contents, I will at once mention the heads under which these problems are considered; viz., relating to the motion of a particle or system of particles, we have

Rectilinear Motion;
Central Forces, and in particular
Elliptic Motion;
The Problem of two Centres;
The Spherical Pendulum;
Motion as affected by the Rotation of the Earth, and Relative Motion in general;
Miscellaneous Problems:
The Problem of three bodies.

And relating to the motion of a solid body, we have

The Transformation of Coordinates;
Principal Axes, and Moments of Inertia;

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Rotation of a Solid Body;
Kinematics of a Solid Body;
Miscellaneous Problems.

As regards the first division of the subject, I remark that the lunar and planetary theories, as usually treated, do not (properly speaking) relate to the problem of three bodies, but to that of disturbed elliptic motion—a problem which is not considered in the present Report. The problem of the spherical pendulum is that of a particle moving on a spherical surface; but, with this exception, I do not much consider the motion of a particle on a given curve or surface, nor the motion in a resisting medium; what is said on these subjects is included under the head Miscellaneous Problems. The first six heads relate exclusively, and the head Miscellaneous Problems relates principally to the motion of a single particle. As regards the second division of the subject, I will only remark that, from its intimate connexion with the theory of the motion of a solid body, I have been induced to make a separate head of the geometrical subject, "Transformation of Coordinates," and to treat of it in considerable detail.

I have inserted at the end of the present Report a list of the memoirs and works referred to, arranged (not, as in the former Report, in chronological order, but) alphabetically according to the authors' names: those referred to in the former Report formed for the purpose thereof a single series, which is not here the case. The dates specified are for the most part those on the title-page of the volume, being intended to show approximately the date of the researches to which they refer, but in some instances a more particular specification is made.

I take the opportunity of noticing a serious omission in my former Report, viz., I have not made mention of the elaborate memoir, Ostrogradsky, "Mémoire sur les équations différentielles rélatives au problème des Isopérimètres," Mém. de St. Pét. t. iv. (6 sér.) pp. 385–517, 1850, which among other researches contains, and that *in the most general form*, the transformation of the equations of motion from the Lagrangian to the Hamiltonian form, and indeed the transformation of the general isoperimetric system (that is, the system arising from any problem in the calculus of variations) to the Hamiltonian form. I remark also, as regards the memoir of Cauchy referred to in the note p. 12 as an *unpublished* memoir of 1831, there is an "Extrait du Mémoire présenté à l'Académie de Turin le 11 Oct. 1831," published in lithograph under the date Turin, 1832, with an addition dated 6 Mar. 1833. The Extract begins thus:—"§ I. Variation des Constantes Arbitraires. Soient données entre la variable t, . . . n fonctions de t désignées par x, y, z . . et n autres fonctions de t désignées par u, v, w, . . $2n$ équations différentielles du prémier ordre et de la forme

$$\frac{dx}{dt}=\frac{dQ}{du},\quad \frac{dy}{dt}=\frac{dQ}{dv},\quad \frac{dz}{dt}=\frac{dQ}{dw},$$
$$\frac{du}{dt}=-\frac{dQ}{dx},\quad \frac{dv}{dt}=-\frac{dQ}{dy},\quad \frac{dw}{dt}=-\frac{dQ}{dz},\ \&c."$$

without explanation as to the origin of these equations; and the formulæ are then given for the variations of the constants in the integrals of the foregoing system; this seems sufficient to establish that Cauchy in the year 1831 was familiar with the Hamiltonian form of the equations of motion.

Bour's "Mémoire sur l'intégration des équations différentielles de la Mécanique," as published, Mém. prés. de l'Inst. t. xiv. pp. 792–821, is substantially the same as the extract thereof in 'Liouville's Journal,' referred to in my former Report; but since the date of that Report there have been published in the 'Comptes Rendus,' 1861 and 1862, several short papers by the same author; also Jacobi's great memoir, see list, Jacobi, Nova Methodus &c. 1862, edited after his decease by Clebsch; some valuable memoirs by Natani and Clebsch (Crelle, 1861 and 1862) relating to the Pfaffian system of equations (which includes those of Dynamics), and Boole "On Simultaneous Differential Equations of the First Order, in which the number of the Variables exceeds by more than one the number of the Equations," Phil. Trans. t. clii. (1862) pp. 437–454.

Rectilinear Motion, Article Nos. 1 to 5.

1. The determination of the motion of a falling body, which is the case of a constant force, is due to Galileo.

2. A variable force, assumed to be a force depending only on the position of the particle, may be considered as a function of the distance from any point in the line, selected at pleasure as a centre of force; but if, as usual, the force is given as a function of the distance from a certain point, it is natural to take that point for the centre of force. The problem thus becomes a particular case of that of central forces; and it is so treated in the 'Principia,' Book I. § 7; the method has the advantage of explaining the paradoxical result which presents itself in the case Force $\propto$ (Dist.)$^{-2}$, and in some other cases where the force becomes infinite. According to theory, the velocity becomes infinite at the centre, but the direction of the motion is there abruptly reversed; so that the body in its motion does not pass through the centre, but on arriving there, forthwith returns towards its original position; of course such a motion cannot occur in nature, where neither a force nor a velocity ever is actually infinite.

3. Analytically the problem may be treated separately by means of the equation $\frac{d^2x}{dt^2}=X$, which is at once integrable in the form $\left(\frac{dx}{dt}\right)^2=C+2\int X\,dx$.

4. The following cases may be mentioned:—

Force $\propto$ Dist. The law of motion is well known, being in fact the same as for the cycloidal pendulum.

Force $\propto$ (Dist.)$^{-2}$, $=\frac{\mu}{x^2}$, which is the case above alluded to.

Assuming that the body falls from rest at a distance a, we have

$$x=a\,(1-\cos\phi),$$

where, if $n=\frac{a^{\frac{3}{2}}}{\sqrt{\mu}}$, ϕ is given in terms of the time by means of the equation

$$nt=\phi-\sin\phi.$$

If the body had initially a small transverse velocity, the motion would be in a very excentric ellipse, and the formulæ are in fact the limiting form of those for elliptic motion.

5. There are various laws of force for which the motion may be determined. In particular it can be determined by means of Elliptic Integrals, in the case of a body attracted to two centres, force $\propto$ (dist.)$^{-2}$: see Legendre, Exercices de Cal. Intég. t. ii. pp. 502–512, and Théorie des Fonct. Ellip. t. i. pp. 531–538.

Central Forces, Article Nos. 6 to 26.

6. The theory of the motion of a body under the action of a given central force was first established in the 'Principia,' Book I. §§ 2 & 3: viz. Prop. I. the areas are proportional to the times, that is (using the ordinary analytical notation), $r^2 d\theta = h dt$, and Prop. VI. Cor. 3, $P \propto \frac{1}{SY^2 . PV}, = h^2u^2\left(\frac{d^2u}{d\theta^2}+u\right)$, so that

$$\frac{d^2u}{d\theta^2}+u-\frac{P}{h^2u^2}=0.$$

7. It is to be noticed that, given the orbit, the law of force is at once determined; and § 2 contains several instances of such determination; thus,

Prop. VII. If a body revolve in a circle, the law of force to a point S is force $\propto \frac{1}{SP^2 . PV^3}$ (P the body, PV the chord through S).

Prop. IX. If a body move in a logarithmic spiral, force $\propto$ (dist.)$^{-3}$.

Prop. X. If a body move in an ellipse, force to centre $\propto$ dist., and as a particular case, if the body move in a parabola under the action of a force parallel to the axis, the force is constant. The particular case of motion in a parabola had been obtained by Galileo.

And § 3. Props. XI. XII. XIII. If a body move in an ellipse, hyperbola, or parabola under the action of a force tending to the focus, force $\propto$ (dist.)$^{-2}$.

8. But Newton had no direct method of solving the inverse problem (which depends on the solution of the differential equation), "Given the force to find the orbit." Thus force $\propto$ (dist.)$^{-2}$, after it has been shown that an ellipse, a hyperbola, and a parabola may each of them be described under the action of such a force. The remainder of the solution consists in showing that, given the initial circumstances of the motion, a conic section (ellipse, parabola, or hyperbola, as the case may be) can be constructed, passing through the point of projection, having its tangent in the direction of the initial motion, and such that the velocity of the body describing the conic section under the action of the given central force is equal to the velocity of projection; which being so, the orbit will be the conic section so constructed. This is what is done, Prop. XVII.; it may be observed that the latus rectum is constructed not very elegantly by means of the latus rectum of an auxiliary orbit.

9. A more elegant construction was obtained by Cotes (see the 'Harmonia Mensurarum,' pp. 103–105, and demonstration from the author's papers in the Notes by R. Smith, pp. 124, 125), depending on the position of a point C, such that the velocity acquired in falling under the action of the central force from C *directly or through infinity** to P the point of projection, is equal to the given velocity of projection.

10. But Newton's original construction is now usually replaced by a construction which employs the space due to the velocity of projection considered as produced by a constant force equal to the central force at the point of projection.

11. Section 9 of Book I. relates to revolving orbits, viz., it is shown that a body may be made to move in an orbit revolving round the centre of force,

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* In the second case C lies on the radius vector produced beyond the centre, and the body is supposed to fall from rest at C (under the action of the central force considered as repulsive) to infinity, and then from the opposite infinity (with an initial velocity equal to the velocity so acquired) to P.

by adding to the central force required to make the body move in the same orbit at rest, a force $\propto$ (dist.)$^{-3}$. This appears very readily by means of the differential equation (*antè*, No. 6), viz. writing therein $P+cu^3$ for P, and then θ', h' in the place of $\theta\sqrt{1-\frac{c}{h^2}}$, $h\sqrt{1-\frac{c}{h^2}}$ respectively, the equation retains its original form, with θ', h', in the place of θ, h respectively.

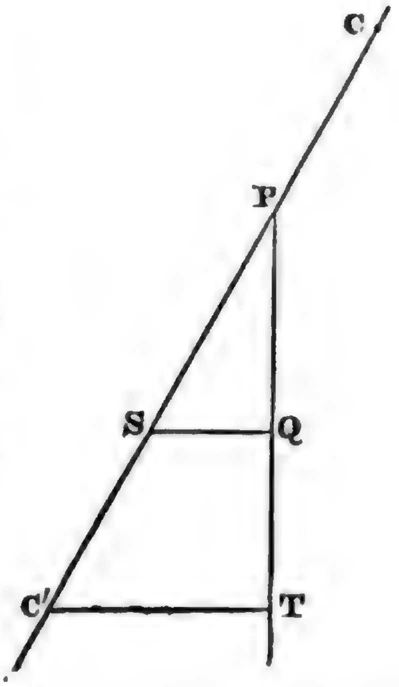
12. It may be remarked that when the original central force vanishes, the fixed orbit is a right line (not passing through the centre of force). It thus appears by § 9 that the curve $u=A\cos(n\theta+B)$ may be described under the action of a force $\propto$ (dist.)$^{-3}$. A proposition in § 2, already referred to, shows that a logarithmic spiral may be described under the action of such a force.

13. But the case of a force $\propto$ (dist.)$^{-3}$ was first completely discussed by Cotes in the 'Harmonia Mensurarum,' pp. 31–35, 98–104, and Notes, pp. 117–173. There are in all five cases, according as the velocity of projection is

1. Less than that acquired in falling from infinity, or say equal to that acquired in falling from a point C to P, the point of projection.
2. Equal to that acquired in falling from infinity.

3, 4, 5. Greater than that acquired in falling from infinity, or say equal to that acquired in falling from a point C′, *through infinity*, to P; viz. P Q being the direction of projection, and S Q, C′T perpendiculars thereon from S and C′ respectively,

3. $SQ<TQ$;
4. $SQ=TQ$;
5. $SQ>TQ$;



the equations of the orbits being

1. $u=A\epsilon^{m\theta}+B\epsilon^{-m\theta}$, A and B same sign, so that rad. vector is never infinite.
2. $u=A\epsilon^{m\theta}$ or $B\epsilon^{-m\theta}$, logarithmic spiral.
3. $u=A\epsilon^{m\theta}+B\epsilon^{-m\theta}$, A and B opposite signs, so that rad. ector becomes infinite.
4. $u=A\theta+B$, $m=0$, reciprocal spiral.
5. $u=A\cos(n\theta+B)$, $m=n\sqrt{-1}$.

14. The before-mentioned equation,

$$\frac{d^2u}{d\theta^2}+u-\frac{P}{h^2u^2}=0,$$

is in effect given (but the equation is encumbered with a tangential force) in Clairaut's "Théorie de la Lune," 1765. It is given in its actual form, and extensively used (in particular for obtaining the above-mentioned equations for Cotes's spirals) in Whewell's 'Dynamics,' 1823. The equation appears to be but little known to continental writers, and (under the form $u''+u-a^2r^2R=0$) it is given *as new* by Schellbach as late as 1853. The formulæ used in place of it are those which give t and θ each of them in terms of r; viz.

$$dt=\frac{rdr}{\{-h^2+r^2(\mathrm{C}-2\int \mathrm{P}dr)\}^{\frac{1}{2}}},$$

$$d\theta=\frac{hdr}{r\{-h^2+r^2(\mathrm{C}-2\int \mathrm{P}dr)\}^{\frac{1}{2}}},$$

which, however, assume that P is a function of r only.

15. Force $\propto(\text{dist.})^{-2}$. The law of motion in the conic sections is implicitly given by Newton's theorem for the equable description of the areas. For the parabola, if a denote the pericentric distance, and f the angle from pericentre or true anomaly, we have

$$t=\frac{a^{\frac{3}{2}}\sqrt{2}}{\sqrt{\mu}}\left(\tan\tfrac{1}{2}f+\tfrac{1}{3}\tan^3\tfrac{1}{2}f\right).$$

For the ellipse we have an angle g, the mean anomaly varying directly as the time $\left(g=nt \text{ if } n=\frac{\sqrt{\mu}}{a^{\frac{3}{2}}}\right)$; an auxiliary angle u, the excentric anomaly, connected with g by the equation

$$g=u-e\sin u;$$

and then the radius vector r and the true anomaly f are given in terms of u by the equations $r=a(1-e\cos u)$, and

$$\cos f=\frac{\cos u-e}{1-e\cos u},\ \sin f=\frac{\sqrt{1-e^2}\sin u}{1-e\cos u},\ \text{and} \therefore \tan\tfrac{1}{2}f=\sqrt{\frac{1+e}{1-e}}\tan\tfrac{1}{2}u.$$

16. It is very convenient to have a notation for $\frac{r}{a}$ and f considered as functions of e, g, and I have elsewhere proposed to write

$$r=a\ \mathrm{elqr}\,(e,g),\ f=\mathrm{elta}\,(e,g),$$

read elqr elliptic quotient radius, and elta elliptic true anomaly.

17. The formulæ for the hyperbola correspond to those for the ellipse, but they contain exponential in the place of circular functions (see *post*, Elliptic Motion).

18. Euler, in the memoir "Determinatio Orbitæ Cometæ Anni 1742," (1743), p. 16 *et seq.*, obtained an expression for the time of describing a parabolic arc in terms of the radius vectors and the chord; viz. these being f, g, and k, the expression is

$$\text{Time}=\frac{1}{6\sqrt{\mu}}\left\{\left(f+g+k\right)^{\frac{3}{2}}-\left(f+g-k\right)^{\frac{3}{2}}\right\},$$

which, however, as remarked by Lagrange, 'Méc. Anal.' t. xi. (3rd edit. p. 28), is deducible from Lemma X. of the third book of the 'Principia.' But the theorem in its actual form is due to Euler.

19. Lambert, in the 'Proprietates Insigniores, &c.' (1761), Theorem VII. Cor. 2, obtained the same theorem, and in section 4 he obtained the corresponding theorem for elliptic motion; viz. the expression for the time is

$$=\frac{a^{\frac{3}{2}}}{\sqrt{\mu}}\left\{\varphi-\phi'-(\sin\phi-\sin\phi')\right\}$$

if

$$\sin\tfrac{1}{2}\phi=\tfrac{1}{2}\sqrt{\frac{f+g-k}{a}},\ \sin\tfrac{1}{2}\phi'=\tfrac{1}{2}\sqrt{\frac{f+g-k}{a}}.$$

The form of the formula is, it will be observed, similar to that for motion in a straight line (*antè*, No. 4), and in fact the motion in the ellipse is, by an ingenious geometrical transformation, made to depend upon that in the straight line. The geometrical theorems upon which the transformation depends are stated, Cayley "On Lambert's Theorem &c." (1861).

20. The theorem was also obtained by Lagrange in the memoir "Recherches &c." (1767) as a corollary to his solution of the problem of two centres; viz. upon making the attractive force of one of the centres equal to zero, and assuming that such centre is situate on the curve, the expression for the time presents itself in the form given by Lambert's theorem.

21. Two other demonstrations of the theorem are given by Lagrange in the memoir "Sur une manière particulière d'exprimer le temps &c." (1778), reproduced in Note V. of the second volume of the last edition (Bertrand's) of the 'Mécanique Analytique.' As M. Bertrand remarks, these demonstrations are very complete, very elegant, and very natural, assuming that the theorem is known beforehand.

Demonstrations were also given by Gauss, "Theoria Motus" (1809), p. 119 *et seq.*; Pagani, "Démonstration d'un théorème &c." (1834); and (in connexion with Hamilton's principal function) by Sir W. R. Hamilton, "On a General Method &c." (1834), p. 282; Jacobi, "Zur Theorie &c." (1837), p. 122; Cayley, "Note on the Theory of Elliptic Motion" (1856).

22. Connected with the problem of central forces, we have Sir W. R. Hamilton's 'Hodograph,' which in the paper (Proc. R. Irish Acad. 1847) is defined, and the fundamental properties stated; viz. if in an orbit round a centre of force there be taken on the perpendicular from the centre on the tangent at each point, a length equal to the velocity at that point of the orbit, the extremities of these lengths will trace out a curve which is the hodograph. As the product of the velocity into the perpendicular on the tangent is equal to twice the area swept out in a unit of time ($vp=h$), the hodograph is the reciprocal polar of the orbit with respect to a circle described about the centre of force, radius $=\sqrt{h}$. Whence also the tangent at any point of the hodograph is perpendicular to the radius vector through the corresponding point of the orbit, and the product of the perpendicular on the tangent into the corresponding radius vector is $=h$.

If force $\propto$ (dist.)$^{-2}$, the hodograph, *quà* reciprocal polar of a conic section with respect to a circle described about the focus, is a circle.

23. The following theorem is also given without demonstration; viz. if two circular hodographs, which have a common chord passing or tending through a common centre of force, be both cut at right angles by a third circle, the times of hodographically describing the intercepted arcs (that is, the times of describing the corresponding elliptic arcs) will be equal.

24. Droop, "On the Isochronism &c." (1856), shows geometrically that the last-mentioned property is equivalent to Lambert's theorem; and an analytical demonstration is also given, Cayley, "A demonstration of Sir W. R. Hamilton's Theorem &c." (1857). See also Sir W. R. Hamilton's 'Lectures on Quaternions' (1853), p. 614.

25. The laws of central force which have been thus far referred to, are force $\propto r$, $\propto\frac{1}{r^2}$, $\propto\frac{1}{r^3}$; and it has been seen that the case of a force $P+\frac{C}{r^3}$ depends

upon that of a force P, so that the motions for the forces $Ar+\frac{C}{r^3}$ and $\frac{B}{r^2}+\frac{C}{r^3}$ are deducible from those for the forces Ar and $\frac{B}{r^2}$ respectively. Some other laws of force, *e. g.* $\frac{A}{r^2}\pm Br$, $\frac{A}{r^2}+\frac{B}{r^3}+\frac{C}{r^4}+\frac{D}{r^5}$, are considered by Legendre, "Théorie des Fonctions Elliptiques" (1825), being such as lead to results expressible by elliptic integrals, and also the law $\frac{M}{r}$, for which the result involves a peculiar logarithmic integral. But the most elaborate examination of the different cases in which the solution can be worked out by elliptic integrals or otherwise is given in Stader's memoir "De Orbitis &c." (1852), where the investigation is conducted by means of the formulæ which give t and θ in terms of r (*antè*, No. 14).

26. In speaking of a central force, it is for the most part implied that the force is a function of the distance: for some problems in which this is not the case, see *post*, Miscellaneous Problems, Nos. 86 and 87.

It is to be noticed that, although the problem of central forces may be (as it has so far been) considered as a problem *in plano* (viz. the plane of the motion has been made the plane of reference), yet that it is also interesting to consider it as a problem in space; in fact, in this case the integrals, though of course involved in those which belong to the plane problem, present themselves under very distinct forms, and afford interesting applications of the theory of canonical integrals, the derivation of the successive integrals by Poisson's method, and of other general dynamical theories. Moreover, in the lunar and planetary theories, the problem must of necessity be so treated. Without going into any details on this point, I will refer to Bertrand's memoir "Sur les équations différentielles de la Mécanique" (1852), Donkin's memoir "On a Class of Differential Equations &c." (1855), and Jacobi's posthumous memoir, "Nova Methodus &c." (1862).

Elliptic Motion, Article Nos. 27–40.

27. The question of the development of the true anomaly in terms of the mean anomaly (Kepler's problem), and of the other developments which present themselves in the theory of elliptic motion, is one that has very much occupied the attention of geometers. The formulæ on which it depends are mentioned *antè*, No. 15; they involve as an auxiliary quantity the excentric anomaly u.

28. Consider first the equation

$$g=u-e\sin u,$$

which connects the mean anomaly g with the excentric anomaly u.

Any function of u, and in particular u itself, and the functions $\begin{smallmatrix}\cos\\ \sin\end{smallmatrix}\, nu$ may be expanded in terms of g by means of Lagrange's theorem (Lagrange, 'Mém. de Berlin,' 1768–1769, "Théorie des Fonctions," c. 16, and "Traité de la Résolution des équations Numériques," Note 11).

29. Considering next the equation

$$\tan \tfrac{1}{2}f=\sqrt{\frac{1+e}{1-e}}\tan \tfrac{1}{2}u,$$

which gives the true anomaly in terms of the excentric anomaly, then, by replacing the circular functions by their exponential values (a process employed by Lagrange, 'Mém. de Berlin,' 1776), f can be expressed in terms of u; viz. the result is

$$f=u+2\lambda\sin u+2\lambda^2\,.\,\tfrac{1}{2}\sin 2u+2\lambda^3\,.\,\tfrac{1}{3}\sin 3u+\&\text{c.},$$

where $\lambda=\dfrac{1-\sqrt{1-e^2}}{e}\left(=\dfrac{e}{1+\sqrt{1-e^2}}\right)$. Hence if u, $\sin u$, $\sin 2u$, &c. are expressed in terms of the mean anomaly, f will be obtained in the form $f=g+$ a series of multiple sines of g, the coefficients of the different terms being given in the first instance as functions of e and λ; and to complete the development λ and its powers have to be developed in powers of e. The solution is carried thus far in the 'Mécanique Analytique' (1788), and in the 'Mécanique Céleste' (1799).

30. We have next Bessel's investigations in the Berlin Memoirs for 1816, 1818, and 1824, and which are carried on mainly by means of the integral

$$2\pi \mathrm{I}_k^h=\int_0^{2\pi}\cos(hu-k\sin u)\,du,$$

and various properties are there obtained and applications made of this important transcendant.

31. Relating to this integral we have Jacobi's memoir, "Formulæ transformationis &c." (1836), Liouville, "Sur l'intégrale $\int_0^{\pi}\cos i(u-x\sin u)\,du$" (1841), and Hansen's "Ermittelung der absoluten Störungen" (1843); the researches of Poisson in the 'Connaissance des Temps' for 1825 and 1836 are closely connected with those of Bessel.

32. A very elegant formula, giving the actual expression of the coefficients considered as functions of e and λ, is given by Greatheed in the paper "Investigation of the General Term &c." (1838); viz. this is

$$f=g+2\Sigma\lambda^r\left\{\epsilon^{\frac{1}{2}re(\lambda+\lambda^{-1})}+\lambda^{-r}\epsilon^{-\frac{1}{2}re(\lambda+\lambda^{-1})}\right\}\frac{\sin rg}{r},$$

where, after developing in powers of λ, the negative powers of λ must be rejected, and the term independent of λ divided by 2. This result is extended to other functions of f, Cayley "On certain Expansions &c." (1842).

33. An expression for the coefficient of the general term as a function of e only is obtained, Lefort, "Expression Numérique &c." (1846). The expression, which, from the nature of the case, is a very complicated one, is obtained by means of Bessel's integral. This is an indirect process which really comes to the combination of the developments of f in terms of u, and u in terms of g; and an equivalent result is obtained directly in this manner, Creedy, "General and Practical Solution &c." (1855).

34. We have also on the subject of these developments the very valuable and interesting researches of Hansen, contained in his 'Fundamenta Nova, &c.' (1838), in the memoir "Ermittelung der absoluten Störungen &c." (1845), and in particular in the memoir "Entwickelung des Products &c." (1853).

35. But the expression for the coefficient of the general term $\begin{matrix}\cos\\ \sin\end{matrix}\,rg$ in any of these expansions is so complicated that it was desirable to have for the coefficients corresponding to the values $r=0, 1, 2, 3, \ldots$ the finally reduced expressions in which the coefficient of each power of e is given as a numerical

fraction. Such formulæ for the development of $\left(\frac{r}{a}-1\right)^m \frac{\cos}{\sin} jf$, where j is a general symbol, the expansion being carried as far as e^7, were given, Leverrier, ‘Annales de l'Observatoire de Paris,’ t. i. (1855).

36. And starting from these I deduced the results given in my “Tables of the Developments, &c.” (1861); viz. these tables give $\left(x=\frac{r}{a}-1\right)$,

$$(x^1, \ldots . x^7),$$

$$(x^0, x^1, \ldots x^7) \frac{\cos}{\sin} jf, j=1 \text{ to } j=7,$$

$$\left(\left(\frac{r}{a}\right)^4, \left(\frac{r}{a}\right)^3 \ldots \log\frac{r}{a}, \left(\frac{r}{a}\right)^{-1}, \ldots \left(\frac{r}{a}\right)^{-5}\right),$$

$$\left(\left(\frac{r}{a}\right)^4, \ldots \left(\frac{r}{a}\right)^1, \left(\frac{r}{a}\right)^{-1}, \ldots \left(\frac{r}{a}\right)^{-5}\right) \frac{\cos}{\sin} jf, j=1 \text{ to } j=7,$$

all carried to e^7.

37. The true anomaly f has been repeatedly calculated to a much greater extent, in particular by Schubert (Ast. Théoriqne, St. Pét. 1822), as far as e^{20}. The expression for $\frac{r}{a}$ as far as e^{13} is given in the same work, and that for $\log\frac{r}{a}$ as far as e^9 was calculated by Oriani, see Introd. to Delambre's ‘Tables du Soleil,’ Paris (1806).

38. It may be remarked that when the motion of a body is referred to a plane which is not the plane of the elliptic orbit, then we have questions of development similar in some measure to those which regard the motion in the orbit; if, for instance, z be the distance from node, ϕ the inclination, and x the reduced distance from node, then $\cos z = \cos\phi \cos x$, from which we may derive $z=x+$ series of multiple sines of x. And there are, moreover, the questions connected with the development of the reciprocal distance of two particles—say $(a^2+a'^2-2aa'\cos\theta)^{-\frac{1}{2}}$—which present themselves in the planetary theory; but this last is a wide subject, which I do not here enter upon. I will, however, just refer to Hansen's memoir, “Ueber die Entwickelung der negativen und ungeraden Potenzen &c.” (1854).

39. The question of the convergence of the series is treated in Laplace's memoir of 1823, where he shows that in the series which express r and f in multiple cosines or sines of g, the coefficient of a term $\frac{\cos}{\sin} ig$, where i is very great, is at most equal in absolute value to a quantity of the form $\frac{A}{i\sqrt{i}}\left(\frac{e}{\lambda}\right)^i$, A and λ being finite quantities independent of i, whence he concludes that, in order to the convergency of the series, the limiting value of the excentricity is $e=\lambda$, the numerical value being $e=0{\cdot}66195$.

40. The following important theorem was established by Cauchy, as part of a theory of the convergence of series in general; viz. so long as e is less than $0{\cdot}6627432$, which is the least modulus of e for which the equations

$$\frac{\pi}{2}=u-e\sin u,\ 1=e\cos u$$

can be satisfied, the development of the true anomaly and other developments in the theory of elliptic motion will be convergent. This was first given in the "Mémoire sur la Mécanique Céleste," read at Turin in 1831, but it is reproduced in the memoir "Considérations nouvelles sur les suites &c.," Mém. d'Anal. et de Phys. Math. t. i. (1840); and see also the memoirs in 'Liouville's Journal' by Puiseux, and his Note i. to vol. ii. of the 3rd ed. of the 'Mécanique Analytique' (1855). There are on this subject, and on subjects connected with it, several papers by Cauchy in the 'Comptes Rendus,' 1840 *et seq.*, which need not be particularly referred to.

The Problem of two Centres, Article Nos. 41 to 64.

41. The original problem is that of the motion of a body acted upon by forces tending to two centres, and varying inversely as the squares of the distances; but, as will be noticed, the solutions apply with but little variation to more general laws of force.

42. It may be convenient to notice that the coordinates made use of (in the several solutions) for determining the position of the body, are either the sum and difference of the two radius vectors, or else quantities which are respectively functions of the sum and the difference of these radius vectors*. If the plane of the motion is not given, then there is a third coordinate, which is the inclination of the plane through the body and the two centres to a fixed plane through the two centres, or say the azimuth of the axial plane, or simply the azimuth.

43. Calling the first-mentioned two coordinates r and s, and the azimuth ψ, the solution of the problem leads ultimately to equations of the form

$$\frac{dr}{\sqrt{\mathrm{R}}}=\frac{ds}{\sqrt{\mathrm{S}}},\quad dt=\frac{\lambda dr}{\sqrt{\mathrm{R}}}+\frac{\mu ds}{\sqrt{\mathrm{S}}},\quad d\psi=\frac{\rho dr}{\sqrt{\mathrm{R}}}+\frac{\sigma ds}{\sqrt{\mathrm{S}}},$$

where R and S are rational and integral functions (of the third or fourth degree, in the case of forces varying as $(\text{dist.})^{-2}$) of r, s respectively (but they are not in general the same functions of r, s respectively); λ and ρ are simple rational functions of r, and μ and σ simple rational functions of s; so that the equations give by quadratures, the first of them the curve described in the axial plane, the second the position of the body in this curve at a given time, and the third of them the position of the axial plane. In the ordinary case, where R and S are each of them of the third or the fourth order, the quadratures depend on elliptic integrals†; but on account of the presence in the formulæ of the two distinct radicals $\sqrt{\mathrm{R}}$, $\sqrt{\mathrm{S}}$, it would appear that the solution is not susceptible of an ulterior development by means of elliptic and Jacobian functions† similar to those obtained in the problems of Rotation and the Spherical Pendulum.

44. It has just been noticed that when R, S are each of them of the fourth order, the quadratures depend on elliptic integrals; in the particular cases in which the relation between r, s is of the form $\frac{m dr}{\sqrt{\mathrm{R}}}=\frac{n ds}{\sqrt{\mathrm{S}}}$, R and S being

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* If v, u are the distances of the body P from the centres A and B, a the distance AB, ζ, η the angles at A and B respectively, and $p=\tan\frac{1}{2}\zeta\tan\frac{1}{2}\eta$, $q=\tan\frac{1}{2}\zeta\div\tan\frac{1}{2}\eta$, then, as may be shown without difficulty, $v+u=a\frac{1+p}{1-p}$, $v-u=a\frac{1-q}{1+q}$, so that p and q are functions of $v+u$ and $v-u$ respectively; these quantities p and q are Euler's original coordinates.

† The elliptic integrals are Legendre's functions F, E, Π; the elliptic and Jacobian functions are sinam., cosam., Δam., and the higher transcendants Θ, H.

the same functions of r, s respectively, and m and n being integers (or more generally for other relations between the forms of R, S given by the theory of elliptic integrals), the equation admits of algebraical integration; but as the relations in question do not in general hold good, the theory of the algebraical integration of the equations plays only a secondary part in the solution of the problem. It is, however, proper to remark that Euler, when he wrote his first two memoirs "On the Problem of the two Centres" (*post*, Nos. 45 and 46), had already discovered and was acquainted with the theory of the algebraic integration of the equation $\frac{m dr}{\sqrt{R}}=\frac{n ds}{\sqrt{S}}$ (R, S, m, n, *ut suprà*), although his memoir, "Integratio æquationis

$$\frac{dx}{\sqrt{A+Bx+Cx^2+Dx^3+Ex^4}}=\frac{dy}{\sqrt{A+By+Cy^2+Dy^3+Ey^4}},"$$

N. Comm. Petrop. t. xii. 1766–1767?, bears in fact a somewhat later date.

45. Having made these preliminary remarks, I come to the history of the problem.

It is I think clear that Euler's *earliest* memoir is the one "De Motu Corporis &c." in the Petersburg Memoirs for 1764 (printed 1766). In this memoir the forces vary as (dist.)$^{-2}$, and the body moves in a given plane. The equations of motion are taken to be

$$\frac{d^2x}{dt^2}=2g\left(-\frac{Ax}{v^3}+\frac{B(a-x)}{u^3}\right),$$
$$\frac{d^2y}{dt^2}=2g\left(-\frac{Ay}{v^3}-\frac{By}{u^3}\right),$$

which, if ζ, η are the inclinations of the distances v, u to the axis respectively (see foot-note to No. 42), lead to

$$dv^2+v^2dt^2=4gdt^2\left(\frac{A}{v}+\frac{B}{u}+\frac{D+E}{a}\right),$$
$$v^2u^2\, d\zeta\, d\eta=2gadt^2\,(A\cos\zeta+B\cos\eta+D),$$

where D, E are constants of integration. Substituting for v, u their values in terms of η, ζ and eliminating dt, Euler obtains

$$\frac{d\zeta\sin\eta}{d\eta\sin\zeta}=\frac{P+\sqrt{P^2-Q^2}}{Q},$$

where

$$\begin{aligned}A\cos\eta+B\cos\zeta+D\cos\zeta\cos\eta+E\sin\zeta\sin\eta&=P,\\ A\cos\zeta+B\cos\eta+D&=Q.\end{aligned}$$

And he then enters into a very interesting discussion of the particular case A=0 or B=0 (viz. the case where one of the attracting masses vanishes, which was of course known to be integrable); and after arriving at some paradoxical conclusions which he does not completely explain, although he remarks that the explanation depends on the circumstance that the integral found is a *singular solution* of a derivative equation, and as such does not satisfy the original equations of motion,—he proceeds to notice that an inquiry into the cause of the difficulty led him to a substitution by which the variables were separated.

46. But in the memoir "Problème, un Corps &c." in the Berlin Memoirs for 1760 (printed 1767), after obtaining the last-mentioned formulæ, he gives

at once, without explaining how he was led to it, the analytical investigation of the substitution in question, viz. in *each* of the two memoirs he in fact writes

$$\frac{d\zeta \sin\eta + d\eta \sin\zeta}{d\zeta \sin\eta - d\eta \sin\zeta} = \sqrt{\frac{\mathrm{P}+\mathrm{Q}}{\mathrm{P}-\mathrm{Q}}},$$

$$\tan\tfrac{1}{2}\zeta = f, \quad \tan\tfrac{1}{2}\eta = g, \quad fg = p, \quad \frac{f}{g} = q,$$

that is

$$p = \tan\tfrac{1}{2}\zeta \tan\tfrac{1}{2}\eta\,; \quad q = \tan\tfrac{1}{2}\zeta \div \tan\tfrac{1}{2}\eta\,;$$

and in terms of these quantities p, q, the equation becomes

$$\frac{dp}{\sqrt{\mathrm{P}}} = \frac{dq}{\sqrt{\mathrm{Q}}},$$

where

$$\mathrm{P} = (\ \ \mathrm{A}+\mathrm{B}+\mathrm{D})p + 2\mathrm{E}p^2 + (-\mathrm{A}-\mathrm{B}+\mathrm{D})p^3,$$

$$\mathrm{Q} = (-\mathrm{A}+\mathrm{B}-\mathrm{D})q + 2\mathrm{E}q^2 + (\ \ \mathrm{A}-\mathrm{B}-\mathrm{D})q^3,$$

so that P and Q are cubic functions (not the same functions) of p and q respectively; and the equation for the time is found to be

$$\frac{dt\sqrt{2g}}{a\sqrt{a}} = \frac{p\,dp}{(1-p)^2\sqrt{\mathrm{P}}} + \frac{q\,dq}{(1+q)^2\sqrt{\mathrm{Q}}},$$

which are the formulæ for the solution of the problem, as obtained in Euler's first and second memoirs.

47. In his third memoir, viz. that "De Motu Corporis &c." in the Petersburg Memoirs for 1765 (printed 1767), Euler considers the body as moving in space, the forces being as before as (dist.)$^{-2}$. Assuming that the coordinates y, z are in the plane perpendicular to the axis, there is in this case the equation of areas $y\frac{dz}{dt} - z\frac{dy}{dt} = \text{const.}$; and writing $y = y'\sin\psi$, $z = y'\cos\psi$, that is, $y' = \sqrt{y^2+z^2}$, and ψ the azimuth, the integral equations for the motion in the variable plane (coordinates x, y') are not materially different in form from those which belong to the motion in a fixed plane, coordinates x, y (see *post*, No. 56, Jacobi); and the last-mentioned equation, which reduces itself to the form $y'^2\frac{d\psi}{dt} = \text{const.}$, gives at once $d\psi$ in a form such as that above alluded to (*antè*, No. 43), and therefore ψ by quadratures. The variables employed by Euler in the memoir in question are

$$v+u,\ v-u \text{ (say } r, s) \text{ and } \psi,$$

v, u being, as above, the distances from the two centres, and ψ the azimuth of the axial plane. The functions of r, s under the radical signs are of the fourth order; this is so, with these variables, even if the motion is in a fixed plane; but this is no disadvantage, since, as is well known, the case of a quartic radical is not really more complicated than that of a cubic radical, the two forms being immediately convertible the one into the other.

48. Lagrange's first memoir (Turin Memoirs, 1766–1769) refers to Euler's three memoirs, but the author mentions that it was composed in 1767 without the knowledge of Euler's third memoir. The coordinates ultimately made use of are $v+u$, $v-u$ (say r, s) and ψ, the same as in Euler's third memoir, and the results consequently present themselves in the like form.

49. If the attractive force of one of the centres is taken equal to zero, then the position of such centre is arbitrary, and it may be assumed that the centre lies on the curve, which is in this case an ellipse (conic section); the expression of the time presents itself as a function of the focal radius vectors and the chord of the arc described; which, as remarked, *antè*, No. 20, leads to Lambert's theorem for elliptic motion.

50. The case presents itself of an ellipse or hyperbola described under the action of the two forces, viz. the equation $\frac{dr}{\sqrt{R}}=\frac{ds}{\sqrt{S}}$ will be satisfied by $r-\alpha=0$, if $r-\alpha$ be a double factor of R, or by $s-\beta=0$, if $s-\beta$ be a double factor of S, a case which is also considered in the 'Mécanique Analytique;' and see in regard to the analytical theory, t. ii. 3rd ed. Note III. by M. Serret, and "Thèse," Liouv. 1848. It is remarked by M. Bonnet, Note IV. and Liouv. t. ix. p. 113, 1844, that the result is a mere corollary of a general theorem, which is in effect as follows, viz. if a particle under the separate actions of the forces F, F′, . . . starting in each case from the same point in the same direction but with the initial velocities v, v', &c. respectively, describe the same curve, then such curve will also be described under the conjoint action of all the forces, provided the body start from the same point in the same direction, with the initial velocity $V=\sqrt{v^2+v'^2+..}$

51. Lagrange's second memoir (same volume of the Turin Memoirs) contains an exceedingly interesting discussion as to the laws of force for which the problem can be solved. Writing U, V, u, v in the place of Lagrange's P, Q, p, q, the equations of motion are

$$\frac{d^2x}{dt^2}+\frac{(x-a)U}{u}+\frac{(x-\alpha)V}{v}=0,$$

$$\frac{d^2y}{dt^2}+\frac{(y-b)U}{u}+\frac{(y-\beta)V}{v}=0,$$

$$\frac{d^2z}{dt^2}+\frac{(z-c)U}{u}+\frac{(z-\gamma)V}{v}=0,$$

where

$$u=\sqrt{(x-a)^2+(y-b)^2+(z-c)^2},$$

$$v=\sqrt{(x-\alpha)^2+(y-\beta)^2+(z-\gamma)^2},$$

and putting also $f\left(=\sqrt{(a-\alpha)^2+(b-\beta)^2+(c-\gamma)^2}\right)$ the distance of the centres, and then $u^2=f^2x$, $v^2=f^2y$, $\frac{U}{u}=X$, $\frac{V}{v}=Y$ (x, y are of course not to be confounded with the coordinates originally so represented), Lagrange obtains the equations

$$\tfrac{1}{2}\frac{d^2x}{dt^2}+Xx+\frac{(x+y-1)Y}{2}+\int(Xdx+Ydy)=0,$$

$$\tfrac{1}{2}\frac{d^2y}{dt^2}+Yy+\frac{(x+y-1)X}{2}+\int(Xdx+Ydy)=0,$$

which he represents by

$$\tfrac{1}{2}\frac{d^2x}{dt^2}+M=0,$$

$$\tfrac{1}{2}\frac{d^2y}{dt^2}+N=0;$$

and he then inquires as to the conditions of integrability of these equations, for which purpose he assumes that the equations multiplied by $m\,dx+n\,dy$ and $\mu\,dx+\nu\,dy$ respectively and added, give an integrable equation.

52. A case satisfying the required conditions is found to be

$$\mathrm{X}=2\alpha+\frac{\beta}{x\sqrt{x}},\ \mathrm{Y}=2\alpha+\frac{\gamma}{y\sqrt{y}},$$

or, what is the same thing,

$$\mathrm{U}=2\alpha u+\frac{\beta f^3}{u^2},\ \mathrm{V}=2\alpha v+\frac{\gamma f^3}{v^2};$$

that is, besides the forces $\frac{\beta f^3}{u^2}, \frac{\gamma f^3}{v^2}$, which vary as $(\text{dist.})^{-2}$, there are the forces $2\alpha u$, $2\alpha v$, varying directly as the distance, and of the same amount at equal distances; or, what is the same thing, there is, besides the forces varying as $(\text{dist.})^{-2}$, a force varying directly as the distance, tending to a third centre midway between the other two, a case which is specially considered in the memoir; it is found that the functions in r, s under the radicals (instead of rising only to the order 4) rise in this case to the order 6.

53. Among other cases are found the following, viz.:—

$$1^\circ.\qquad \mathrm{U}=\alpha u+\frac{7\lambda}{f^2}u^3+\frac{5\lambda}{f^4}u^5,$$

$$\mathrm{V}=\alpha v+\frac{7\lambda}{f^2}v^3+\frac{5\lambda}{f^4}v^5;$$

$$2^\circ.\qquad \mathrm{U}=\alpha u+\frac{\beta}{f^2}u^3,$$

$$\mathrm{V}=\delta v+\frac{\epsilon}{f^2}v^3,$$

where $\beta=\epsilon$, or else $\alpha\epsilon=\beta\delta=2\beta\epsilon$.

In regard to the subject of this second memoir of Lagrange, see *post*, Miscellaneous Problems, Liouville's Memoirs, Nos. 100 to 105.

54. In the 'Mécanique Analytique' (1st ed. 1788, and 2nd ed. t. ii. 1813), Lagrange in effect reproduces his solution for the above-mentioned law of force (say $\mathrm{U}=\frac{\alpha}{u^2}+2\gamma u$, $\mathrm{V}=\frac{\beta}{v^2}+2\gamma v$)*. There are even in the third edition a few trifling errors of work to be corrected. The remarks above referred to, as made by Lagrange in his first memoir, are also reproduced (see *antè*, Nos. 49 and 50).

55. Legendre, "Exercices de Calcul Intégral," t. ii. (1817), and "Théorie des Fonctions Elliptiques," t. i. (1825), uses p^2 and q^2 in the place of Euler's p, q; the forces are assumed to vary as $(\text{dist.})^{-2}$, and in consequence of the change Euler's cubic radicals are replaced by quartic radicals involving only even powers of p and q respectively; that is, the radicals are in a form adapted for the transformation to elliptic integrals; in certain cases, however, it becomes necessary to attribute to Legendre's variables p and q imaginary values. The various cases of the motion are elaborately discussed by means of the elliptic integrals; in particular Legendre notices certain cases in which the

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* In the 'Mécanique Analytique,' Lagrange's letters are r, q for the distances $r+q=s$, $r-q=u$: the change in the present Report was occasioned by the retention of p, q or Euler's variables.

motion is oscillatory, and which, as he remarks, seem to furnish the first instance of the description by a free particle of only a finite portion of the curve which is analytically the orbit of the particle; there is, however, nothing surprising in this kind of motion, although its existence might easily not have been anticipated.

56. § 26 of Jacobi's memoir "Theoria Novi Multiplicatoris &c." (1845) is entitled "Motus puncti versus duo centra secundum legem Neutonianum attracti." The equations for the motion in space are by a general theorem given in the memoir "De Motu puncti singularis" (1842), reduced to the case of motion in a plane: viz. if x, y are the coordinates, the centre point of the axis being the origin, and y being at right angles to the axis, and if the distance of the centres is $2a$; then the only difference is that to the expression for $\frac{d^2y}{dt^2}$ there is added a term $\frac{\alpha^2}{y^3}$, which arises from the rotation about the axis. Two integrals are obtained, one the integral of *Vis Viva*, and the other of them an integral similar to one of those of Euler's or Lagrange's. And then x', y' being the differential coefficients of x, y with regard to the time, the remaining equation may be taken to be $y'dx-x'dy=0$, where x', y' are to be expressed as functions of x, y by means of the two given integrals. This being so, the principle of the Ultimate Multiplier* furnishes a multiplier of this differential equation, and the integral is found to be

$$\int \frac{y'dx-x'dy}{xy\,(x'^2-y'^2)+(a^2-x^2+y^2)\,x'y'}=\epsilon,$$

the quantity under the integral sign being a complete differential. To verify *à posteriori* that this is so, Jacobi introduces the auxiliary quantities λ', λ'' defined as the roots of the equation $\lambda^2+\lambda(x^2+y^2-a^2)-a^2y^2=0$, which in fact, if as before u, v are the distances from the centres, leads to

$$u+v=2\sqrt{a^2-\lambda'},\ u-v=2\sqrt{a^2-\lambda''},$$

so that λ', λ'' are functions of $u+v$, $u-v$ respectively; and the formulæ, as ultimately expressed in terms of λ', λ'', are substantially of the same form with those of Euler and Lagrange.

57. The investigations contained in Liouville's three memoirs "Sur quelques cas particuliers &c." (1846), find their chief application in the problem of two centres, and by leading in the most direct and natural manner to the general law of force for which the integration is possible, they not only give some important extension of the problem, but they in fact exhibit the problem itself and the preceding solutions of it in their true light. But as they do not relate to this problem exclusively, it will be convenient to consider them separately under the head Miscellaneous Problems.

58. In Serret's 'Thèse sur le Mouvement &c.' (1848), the problem is very elegantly worked out according to the principles of Liouville's memoirs as follows: viz. assuming that the expression of the distance between two consecutive positions of the body is

$$ds^2=\lambda(md\mu^2+nd\nu^2)+\lambda''d\gamma^2,$$

where m, n are functions of μ, ν respectively, and if the forces can be represented by means of a force-function U, then the motion can be determined,

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* Explained in Jacobi's memoir "Theoria Novi Multiplicatoris &c.," Crelle, tt. xxvii. xxviii. xxix. 1844–45.

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provided only λ, λU, $\frac{\lambda''}{\lambda}$ are of the forms

$$\lambda=\phi\mu-\Phi\nu,$$
$$\lambda U=\psi\mu-\Psi\nu,$$
$$\frac{\lambda}{\lambda''}=\varpi\mu-\Pi\nu,$$

where the functional symbols ϕ, Φ, &c. denote any arbitrary functions whatever.

59. It is then assumed that μ, ν are the parameters of the confocal ellipses and hyperbolas situate in the moveable plane through the axis, viz. that we have

$$\frac{x^2}{\mu^2}+\frac{y^2}{\mu^2-b^2}=1,$$
$$\frac{x^2}{\nu^2}-\frac{y^2}{b^2-\nu^2}=1,$$

(the origin is midway between the two centres, $2b$ being their distance; $\frac{1}{2}\mu$, $\frac{1}{2}\nu$ are in fact equal to the sum and difference $u+v$, $u-v$ of the two centres respectively); and that the position of the moveable plane is determined by means of γ, the inclination to a fixed plane through the axis, or say, as before, its azimuth. In fact, with these values of the coordinates, the expression of ds^2 is

$$ds^2=(\mu^2-\nu^2)\left(\frac{d\mu^2}{\mu^2-b^2}+\frac{d\nu^2}{b^2-\nu^2}\right)+\frac{(\mu^2-b^2)(b^2-\nu^2)}{b^2}d\gamma^2,$$

which is of the required form. And moreover if the forces to the two centres vary as (dist.)$^{-2}$, and there is besides a force to the middle point varying as the distance, then

$$U=\frac{g}{\mu+\nu}+\frac{g'}{\mu-\nu}+K(\mu^2+\nu^2-b^2),$$

whence (observing that $\lambda=\mu^2-\nu^2$) λU is of the required form. The equations obtained by substituting for U the above value give the ordinary solution of the problem.

60. Liouville's note to the last-mentioned memoir (1848) contains the demonstration of a theorem obtained by a different process in his *second* memoir, but which is in the present note, starting from Serret's formulæ, demonstrated by the more simple method of the *first* memoir, viz., it is shown that the motion can be obtained if the two centres, instead of being fixed, revolve about the point midway between them in a circle in such manner that the diameter through the two centres always passes through the projection of the body on the plane of the circle. It will be observed that the circular motion of the two centres is neither a uniform nor a given motion, but that they are, as it were, carried along with the moving body.

61. In Desboves's memoir "Sur le Mouvement d'un point matériel &c." (1848), the author developes the solution of the foregoing problem of moving centres, chiefly by the aid of the method employed in Liouville's *second* memoir. And he shows also that the methods of Euler and Lagrange for the case of two fixed centres apply with modification to the more complicated problem of the moving centres.

62. The problem of two centres is considered in Bertrand's "Mémoire sur les équations différentielles &c." (1852), by means of Jacobi's form of the

equations of motion, viz., the problem is reduced to a plane one by means of the addition of a force $\propto \frac{1}{y^3}$ (*antè*, No. 56).

63. Cayley's "Note on Lagrange's Solution &c." (1857) is merely a reproduction of the investigation in the 'Mécanique Analytique;' the object was partly to correct some slight errors of work, and partly to show what were the combinations of the differential equations, which give at once the integrals of the problem.

64. In § II. of Bertrand's "Mémoire sur quelques unes des formes &c." (1857), the following question is considered, viz., assuming that the dynamical equations

$$\frac{d^2x}{dt^2}=\frac{dU}{dx},\quad \frac{d^2y}{dt^2}=\frac{dU}{dy},$$

have an integral of the form

$$\alpha=Px'^2+Qx'y'+Ry'^2+Sy'+Tx'+K$$

(where α is the arbitrary constant, and P, Q . . . K are functions of x and y), it is required to find the form of the force-function U. It is found that U must satisfy a certain partial differential equation of the second order, the general solution of which is not known; but taking U to be a function of the distance from any fixed point (or rather the sum of any number of such functions), it is shown that the *only* case in which the differential equations for the motion of a point attracted to a fixed centre of forces have an integral of the form in question is the above-mentioned one of two centres, each attracting according to the inverse square of the distance, and a third centre midway between them, attracting as the distance.

The Spherical Pendulum, Article Nos. 65 to 73.

65. The problem is obviously the same as that of a heavy particle on the surface of a sphere.

I have not ascertained whether the problem was considered by Euler. Lagrange refers to a solution by Clairaut, Mém. de l'Acad. 1735.

The question was considered by Lagrange, Méc. Anal. 1st edit. p. 283. The angles which determine the position are ψ the inclination of the string to the horizon, ϕ the inclination of the vertical plane through the string to a fixed vertical plane, or say the azimuth. And then forming the equations of motion, two integrals are at once obtained; these are the integrals of *Vis Viva*, and an integral of areas. And these give equations of the form $dt=$funct. $(\psi)\, d\psi$, $d\phi=$funct. $(\psi)d\psi$; so that t, ϕ are each of them given by a quadrature in terms of ψ, which is the point to which the solution is carried. It is noticed that ψ may have a constant value, which is the case of the conical pendulum.

66. In the second edition, t. xi. p. 197 (1815), the solution is reproduced; only, what is obviously more convenient, the angles are taken to be

ψ, the inclination to the vertical,
ϕ, the azimuth.

It is remarked that ψ will always lie between a greatest value α and a least value β, and the integrals are transformed by introducing therein instead of ψ the angle σ, which is such that

$$\cos\psi=\cos\alpha\sin^2\sigma+\cos\beta\cos^2\sigma,$$

by which substitution they assume a more elegant form, involving only the radical

$$\sqrt{1+k^2(\cos\beta-\cos\alpha)\cos 2\sigma},$$

where k is a constant depending on $\cos\alpha$, $\cos\beta$; and the integration is effected approximately in the case where $\cos\beta-\cos\alpha$ is small.

M. Bravais has noticed, however, that by reason of some errors in the working out, Lagrange has arrived at an incorrect value for the angle Φ, which is the apsidal angle, or difference of the azimuths for the inclinations α and β: see the 3rd edition (1855), Note VII., where M. Bravais resumes the calculation, and he arrives at the value $\Phi=\frac{\pi}{2}(1+\frac{3}{8}\alpha\beta)$, α and β being small.

Lagrange considers also the case where the motion takes place in a resisting medium, the resistance varying as velocity squared.

67. A similar solution to Lagrange's, not carried quite so far, is given in Poisson's 'Mécanique,' t. i. pp. 385 *et seq.* (2nd ed. 1833).

A short paper by Puiseux, "Note sur le Mouvement d'un point matériel sur une sphère" (1842), shows merely that the angle Φ is $>\frac{\pi}{2}$.

68. The ulterior development of the solution consists in the effectuation of the integrations by the elliptic and Jacobian functions. It is proper to remark that the dynamical problem the solution whereof by such functions was first fairly worked out, is the more difficult one of the rotation of a solid body, as solved by Jacobi (1839), in completion of Rueb's solution (1834), *post*, Nos. 186 and 197.

69. In relation to the present problem we have Gudermann's memoir "De pendulis sphæricis &c." (1849), who, however, does not arrive at the actual expressions of the coordinates in terms of the time; and the perusal of the memoir is rendered difficult by the author's peculiar notations for the elliptic functions*.

70. It would appear that a solution involving the Jacobian functions was obtained by Durège, in a memoir completed in 1849, but which is still unpublished; see § XX. of his 'Theorie der elliptischen Functionen' (1861), where the memoir is in part reproduced. It is referred to by Richelot in the Note presently mentioned.

71. We have next Tissot's 'Thèse de Mécanique,' 1852, where the expressions for the variables in terms of the time are completely obtained by means of the Jacobian functions H, Θ, and which appears to be the earliest published one containing a complete solution and discussion of the problem.

72. Richelot, in the Note "Bemerkungen zur Theorie des Raumpendels" (1853), gives also, but without demonstration, the final expressions for the coordinates in terms of the time.

Donkin's memoir "On a Class of Differential Equations &c." (1855) contains (No. 59) an application to the case of the spherical pendulum.

73. The first part of the memoir by Dumas, "Ueber die Bewegung des Raumpendels," &c. (1855), comprises a very elegant solution of the problem of the spherical pendulum based upon Jacobi's theorem of the Principal Function (1837), and which is completely developed by the elliptic and Jacobian functions. The latter part of the memoir relates to the effect of the rotation of the Earth; and we thus arrive at the next division of the general subject.

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* The mere use of sn., cn., dn. as an abbreviation of the somewhat cumbrous sinam., cosam., Δam. of the 'Fundamenta Nova' is decidedly convenient.

Motion as affected by the Rotation of the Earth, and Relative Motion in general.
Article Nos. 74 to 85.

74. Laplace (Méc. Céleste, Book X. c. 5) investigates the equations for the motion of a terrestrial body, taking account of the rotation of the Earth (and also of the resistance of the air), and he applies them to the determination of the deviations of falling bodies, &c. He does not, however, apply them to the case of the pendulum.

75. We have also the memoir of Gauss, "Fundamental-gleichungen, &c." (1804): the equations ultimately obtained are similar to those of Poisson. I have not had the opportunity of consulting this memoir.

76. Poisson, in the "Mémoire sur le mouvement des Projectiles &c." (1838), also obtains the general equations of motion, viz. (omitting terms involving n^2), these may be taken to be

$$\begin{aligned}\frac{d^2x}{dt^2}&= X+2n\left(\frac{dy}{dt}\sin\beta+\frac{dz}{dt}\cos\beta\right),\\ \frac{d^2y}{dt^2}&= Y+2n\frac{dx}{dt}\sin\beta,\\ \frac{d^2z}{dt^2}&=g+Z+2n\frac{dx}{dt}\cos\beta\end{aligned}$$

(see p. 20), where the axes of x, y, z are fixed on the Earth and moveable with it: viz., z is in the direction of gravity; x, y in the directions perpendicular to gravity, viz., y in the plane of the meridian northwards, x westwards; g is the actual force of gravity as affected by the resolved part of the centrifugal force; β is the latitude. There are some niceties of definition which are carefully given by Poisson, but which need not be noticed here.

77. Poisson applies his formulæ incidentally to the motion of a pendulum, which he considers as vibrating in a plane; and after showing that the time of oscillation is not sensibly affected, he remarks that upon calculating the force perpendicular to the plane of oscillation, arising from the rotation of the Earth, it is found to be too small sensibly to displace the plane of oscillation or to have any appreciable influence on the motion—a conclusion which, as is well known, is erroneous. He considers also the motion of falling bodies, but the memoir relates principally to the theory of projectiles.

78. That the motion of the spherical pendulum is sensibly affected by the rotation of the Earth is the well-known discovery of Foucault; it appears by his paper, "Démonstration Physique &c.," Comptes Rendus, t. xxxii. 1851, that he was led to it by considering the case of a pendulum oscillating at the pole; the plane of oscillation, if actually fixed in space, will by the rotation of the Earth appear to rotate with the same velocity in the contrary direction; and he remarks that although the case of a different latitude is more complicated, yet the result of an apparent rotation of the plane of oscillation, diminishing to zero at the equator, may be obtained either from analytical or from mechanical and geometrical considerations. Some other Notes by Foucault on the subject are given, 'Comptes Rendus,' t. xxxv. (1853).

79. An analytical demonstration of the theorem was given by Binet, 'Comptes Rendus,' t. xxxii. (1851), and by Baehr (1853). Various short papers on the subject will be found in the 'Philosophical Magazine,' and elsewhere.

80. In regard to the above-mentioned problem of falling bodies, we have a Note by W. S., Camb. and Dub. M. Journ. t. iii. (1848), containing some errors

which are rectified in a subsequent paper, "Remarks on the Deviation of Falling Bodies," &c. t. iv. (1849), by Dr. Hart and Professor W. Thomson.

81. The theory of relative motion is considered in a very general manner in M. Quet's memoir, "Des Mouvements relatifs en général &c." (1853). Suppose that x, y, z are the coordinates of a particle in relation to a set of moveable axes; let ξ', η', ζ' be the coordinates of the moveable origin in reference to a fixed set of axes, and treating the accelerations $\frac{d^2\xi'}{dt^2}, \frac{d^2\eta'}{dt^2}, \frac{d^2\zeta'}{dt^2}$ as if they were coordinates, let these, when resolved along the moveable axes, give u', v', w': suppose, moreover, that p, q, r denote the angular velocities of the system of the moveable axes (or axes of x, y, z) round the axes of x, y, and z respectively; u', v', w', p, q, r are considered as given functions of the time, and then, if

$$u=\frac{d^2x}{dt^2}+2\left(q\frac{dz}{dt}-r\frac{dy}{dt}\right)+z\frac{dq}{dt}-y\frac{dr}{dt}+q\,(py-qx)-r\,(rx-pr)+u',$$

$$v=\frac{d^2y}{dt^2}+2\left(r\frac{dx}{dt}-p\frac{dz}{dt}\right)+x\frac{dr}{dt}-z\frac{dp}{dt}+r\,(qz-ry)-p\,(py-qx)+v',$$

$$w=\frac{d^2z}{dt^2}+2\left(p\frac{dy}{dt}-q\frac{dx}{dt}\right)+y\frac{dp}{dt}-x\frac{dq}{dt}+p\,(rx-pz)-q\,(qz-ry)+w',$$

it is shown that the equations of motion are to be obtained from the equation

$$\Sigma m\,[(u-\mathrm{X})\delta x+(v-\mathrm{Y})\delta y+(w-\mathrm{Z})\delta z]=0,$$

where $\delta x, \delta y, \delta z$ are the virtual velocities of the particle m in the directions of the moveable axes. This equation is in fact obtained as a transformation of the equation

$$\Sigma m\left[\left(\frac{d^2\xi}{dt^2}-\mathrm{X}\right)\delta\xi+\left(\frac{d^2\eta}{dt^2}-\mathrm{Y}\right)\delta\eta+\left(\frac{d^2\zeta}{dt^2}-\mathrm{Z}\right)\delta\zeta\right]=0,$$

which belongs to a set of fixed axes of ξ, η, ζ.

82. The equations for the motion of a free particle are of course $u=\mathrm{X}$, $v=\mathrm{Y}$, $w=\mathrm{Z}$. In the case where the moveable axes are fixed on the Earth, and moveable with it (the diurnal motion being alone attended to), these lead to equations for the motion of a particle in reference to the Earth, similar to those obtained by Gauss and Poisson. The formulæ are applied to the case of the spherical pendulum, which is developed with some care; and Foucault's theorem of the rotation of the plane of oscillation very readily presents itself. The general formulæ are applied to the relative motion of a solid body, and in particular to the question of the gyroscope; the memoir contains other interesting results.

83. The principal memoirs on the motion of the spherical pendulum, as affected by the rotation of the Earth, are those of Hansen, "Theorie der Pendelbewegung &c." (1853), which contains an elaborate investigation of all the physical circumstances (resistance of the air, torsion of the string, &c.) which can affect the actual motion, and the before-mentioned memoir by Dumas, "Ueber der Bewegung des Raumpendels &c." (1855). The investigation is conducted by means of the variation of the constants; the integrals for the undisturbed problem were, as already noticed, obtained by means of Jacobi's Principal Function, that is, in a form which leads at once to the expressions for the variation of the constants; and the investigation appears to be carried out in a most elaborate and complete manner.

84. In concluding this part of the subject I refer to Mr. Worms's work, 'The Rotation of the Earth' (1862), where the last-mentioned questions

(falling bodies, the pendulum, and the gyroscope) are, in reference to the proofs they afford of the rotation of the Earth, considered as well in an experimental as in a mathematical point of view. The second part of the volume contains the theory (after Laplace and Gauss) of falling bodies, that of the pendulum (after Hansen), and that of the gyroscope (after Yvon Villarceau); and the whole appears to be a complete and satisfactory *résumé* of the experimental and mathematical theories to which it relates.

85. We have also Cohen "On the Differential Coefficients and Determinants of Lines &c." (1862), where the equations for relative motion are obtained in a very elegant manner. The fundamental notion of the memoir may be considered to be the dealing *directly* with lines, velocities, &c., which are variable in direction as well as in magnitude, instead of referring them, as in the ordinary analytical method, to axes fixed in space. The memoir is a highly interesting and valuable one, and the results are brought out with great facility; but I cannot but think that the great care required to apply the method correctly is an objection to it, if used otherwise than by way of interpretation of previously obtained results, and that the ordinary method is preferable.

I may remark that the theory of relative motion connects itself with the lunar and planetary theories as regards the reference of the plane of the orbit to the variable ecliptic, and as regards the variations of the position of the orbit; but this is a subject which I have abstained from entering upon.

Miscellaneous Problems. Article Nos. 86 to 111 (several subheadings).

Motion of a single particle.

86. Jacobi, in the memoir "De Motu puncti singularis" (1842), notices (§ 5) the case of a body acted on by a central force which is any homogeneous function of the degree -2 of the coordinates; or representing these by $r\cos\phi$, $r\sin\phi$, then the force is $=\frac{\Phi}{r^2}$, where Φ is any function of the angle ϕ. In fact, after integrating by a process different from the ordinary one the case of a central force $\propto\frac{1}{r^2}$, he remarks that the method in fact applies to the more general law of force just mentioned.

87. Jacobi, in the memoir "Theoria Novi Multiplicatoris &c." (1845), considers (§ 25) the case of a body acted on by a central force P a function of the distance, and besides by forces X and Y, which are homogeneous functions of the degree -3 of the coordinates (x, y); viz. the equations of motion are in this case

$$\frac{d^2x}{dt^2}=-\frac{\mathrm{P}x}{r}+\mathrm{X},$$
$$\frac{d^2y}{dt^2}=-\frac{\mathrm{P}y}{r}+\mathrm{Y},$$

and there is an integral

$$\tfrac{1}{2}(xy'-x'y)^2-\int x^2(x\mathrm{Y}-y\mathrm{X})\,d\frac{y}{x}=\text{const}.$$

(the function under the integral sign is obviously a function of the degree 0 in (x, y), that is, it is a function of $\left.\frac{y}{x}\right)$. If X, Y are the derived functions of a force-function U of the degree -2 in (x, y), then there is, besides, the integral of *Vis Viva*, and thence a third integral is obtained by means of the theorem of the Ultimate Multiplier. It may be noticed that in the last-mentioned case the force-function is of the form $\frac{\Phi}{r^2}$, so that if we represent also the central force by means of a force-function R (=function of r), then the entire force-function is $R+\frac{\Phi}{r^2}$. The case is a very interesting one; it includes that considered § iv. of Bertrand's "Mémoire sur les équations différentielles de la Mécanique" (1852), where the force-function is of the form $=\frac{\Phi}{r^2}$.

Motion of three mutually attracting bodies in a right line.

88. The problem is considered by Euler in the memoir "De Motu rectilineo &c." (1765), the forces being as the inverse square of the distance; and a solution is obtained for an interesting particular case. Let A, B, C be the masses, and suppose that at the commencement of the motion the distances CB, BA are in the ratio $\alpha:1$, and that the velocities (assumed to be in the same sense) are proportional to the distances from a fixed point. Then, if α be the real root (there is only one) of the equation of the fifth order

$$C(1+3\alpha+3\alpha^2)=A\alpha^3(\alpha^2+3\alpha+3)+B(\alpha+1^2)(\alpha^3-1),$$

the distances CB, BA will always continue in the ratio $\alpha:1$. It may be added that the distances CB, BA each of them vary as r^2-a^2, where a is a constant, and r is, according to the initial circumstances, a function of t defined by one or the other of the two equations

$$t=n^3r\sqrt{r^2-a^2}-n^3a^2\log\frac{r+\sqrt{r^2-a^2}}{a},$$

$$t=n^3r\sqrt{a^2-r^2}+n^3a^2\sin^{-1}\frac{r}{a}.$$

89. The bodies are considered as restricted to move in a given line; but it is clear that if the bodies, considered as free points in space, are initially in a line, and the initial velocities are also in this line, then the bodies will always continue in this line, which will be a fixed line in space. But if the distances and velocities are as above, except only that the velocities, instead of being along the line, are parallel to each other in any direction whatever, then the bodies will always continue in a line, which is in this case a moveable line in space (see *post*, No. 93).

90. Euler resumes the problem in the memoir of 1776 in the 'Nova Acta Petrop.' The distances AB, BC being p and q, then

$$\frac{d^2p}{dt^2}=-\frac{A+B}{p^2}+\frac{C}{q^2}-\frac{C}{(p+q)^2},$$

$$\frac{d^2q}{dt^2}=\frac{A}{p^2}-\frac{A}{(p+q)^2}-\frac{B+C}{q^2};$$

and in particular he considers the before-mentioned case of a solution of the form $p=nq$; and also the particular problem where one of the masses vanishes, $C=0$; in this case, introducing (instead of p, q) the new variables u, s, where $q=up$, $dq=sdp$ (a transformation suggested by the homogeneity of the equations), and making, moreover, the particular supposition that the integral of the first equation is $\left(\frac{dp}{dt}\right)^2=\frac{2(A+B)}{p}$ (viz. making the constant of integration to vanish), he obtains between s and u the equation of the first order

$$2(\mathrm{A}+\mathrm{B})\frac{ds}{du}(s-u)=(\mathrm{A}+\mathrm{B})s+\mathrm{A}-\frac{\mathrm{A}}{(1+u)^2}-\frac{\mathrm{B}}{u^2},$$

which, however, he is not able to integrate.

91. Jacobi has given in the memoir "Theoria Novi Multiplicatoris" (1845) (§28, entitled "De Problemate trium corporum in eadem recta motorum. Substitutio Euleriana. Theoremata de viribus homogeneis") a very symmetrical and elegant investigation of the same problem. The centre of gravity being assumed to be at rest, the coordinates x, x_1, x_2 of the three bodies are in the first instance expressed as linear functions of the two variables u, v (being, as Jacobi remarks, the transformation employed in his memoir "Sur l'élimination des Nœuds" (1843), *post*, No. 114), $\frac{d^2u}{dt^2}$ and $\frac{d^2v}{dt^2}$ come out respectively equal to homogeneous functions of the degree -2 of these variables u and v, and the integral of *Vis Viva* exists. The subsequent transformation consists in the introduction of the variables r, ϕ, s, η, where $u=r\cos\phi$, $v=r\sin\phi$, $s=\sqrt{r}\,\frac{dr}{dt}$, $\eta=\sqrt{r^3}\,\frac{d\phi}{dt}$; this gives a system of equations independent of r; viz.,

$$d\phi : ds : d\eta=\eta : \tfrac{1}{2}s^2+\eta^2-\Phi : -\tfrac{1}{2}s\eta+\Phi',$$

where Φ is a given function of ϕ, and Φ' is the derived function. If these equations were integrated, the equation of *Vis Viva* gives at once $r=\frac{1}{h}(\Phi-\tfrac{1}{2}(s^2+\eta^2))$; and finally the time t would be given by a quadrature. The system of three equations has the multiplier $\mathrm{M}=\frac{1}{\sqrt{\phi-\frac{1}{2}(s^2+\eta^2)}}$, hence if one integral were known the other would be at once furnished by the general theory. There is a simplification in the form of the solution if h (the constant of *Vis Viva*) $=0$. It is remarked that the method is equally applicable when the force varies as *any* power of the distance; and moreover that when the force varies as $(\text{dist.})^{-3}$, then the solution depends upon one quadrature only.

92. The concluding part of the section relates to the very general problem of a system of n particles acted on by any forces homogeneous functions of the coordinates (this includes the case of n particles mutually attracting each other according to a power of the distance), and this more general investigation illustrates the method employed in regard to the three bodies in a line. It may be remarked that in the general theorem for the n particles "sint vires &c.," the constant of *Vis Viva* is supposed to vanish.

Particular cases of the motion of three bodies.

93. In the case of three bodies attracting each other according to the inverse square of the distance, the bodies may move in such manner as to be constantly in a line (a moveable line in space); this appears by the memoir, Euler, "Considérations générales, &c." (1764), in which memoir, however (which it will be observed precedes the memoir "De Motu rectilineo &c." (1765), referred to No. 88), Euler assumes that the mass of one of the bodies is so small as not to affect the relative motion of the other two. Calling the bodies the Sun, Earth, and Moon, and taking the masses to be 1, m, 0, then a result obtained is, that in order that the Moon may be perpetually

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in conjunction, its distance must be to that of the Sun as $\alpha:1$, where $m(1-\alpha)^2=3\alpha^3-3\alpha^4+\alpha^5$, or $\alpha=\sqrt[3]{\tfrac{1}{3}m}$ nearly. It appears, however (*antè*, No. 88), that the foregoing restriction as to the masses is unnecessary, and, as will be mentioned, the problem has since been treated without such restriction. Euler investigates the motion in the case where the initial circumstances are nearly but not exactly as originally supposed; this assumes, however, that the motion is stable—*i. e.* that the bodies will continue to move nearly, but not exactly as originally supposed, which is at variance with the conclusions of Liouville's memoir, *post*, No. 95. I have not examined the cause of this discrepancy.

94. In the 'Mécanique Céleste' (1799), Book x. c. 6, Laplace considers two cases where the motion can be exactly determined.

1°. Force varies as any function of the distance. It is shown that the motion may be such that the bodies form always an equilateral triangle of variable magnitude—the motion of each body about the centre of gravity being the same as if that point were a centre of force attracting the body according to a similar law.

2°. Force $\propto(\text{dist.})^n$. The motion may be such that the three bodies are always in a right line (moveable in space), the relative distances being in fixed ratios to each other. In particular, if force $\propto$ $(\text{dist.})^{-2}$, then m, m', m'' being the masses, the quantity z which determines the ratio of the distances $m''m'$, $m'm$ is given by

$$0=mz^2[(1+z)^3-1]-m'(1+z)^2(1-z^3)-m''[(1+z)^3-z^3]=0,$$

which is, in fact, the formula in Euler's memoir "De Motu rectilineo &c."

95. Liouville's memoir "Sur un cas particulier &c." (1842) has for its object to show that if the initial circumstances are not precisely as supposed in the second of the two cases considered by Laplace, or, what is the same thing, in Euler's memoir "Considérations générales &c.," then the motion is unstable; the instability manifests itself in the usual manner, viz. the expressions for the deviations from the normal positions are found to contain real exponentials which increase indefinitely with the time.

96. It may be proper to refer here to Jacobi's theorem, 'Comptes Rendus,' t. iii. p. 61 (1836), quoted in the foot-note p. 15 of my Report of 1857, which relates to the motion of a point *without mass* revolving round the Sun, and disturbed by a planet moving in a circular orbit, and properly belongs (as I have there remarked) to the problem of two centres, one of them moveable and the other revolving round it in a circle with uniform velocity. The theorem (given without demonstration by Jacobi) is proved by Liouville in his last-mentioned memoir, and he remarks that the theorem follows very simply as a corollary of the theorem by Coriolis, "On the Principle of *Vis Viva* in Relative Motions," Journ. de l'Ecole Polyt. t. xiii. p. 268 (1832). There is, however, no difficulty in proving the theorem; another proof is given, Cayley, "Note on a Theorem of Jacobi's &c." (1862).

Motion in a resisting medium.

97. I do not consider the various integrable cases of the motion of a particle in a resisting medium, the resistance varying with the velocity according to some assumed law, the particle being either not acted on by any force, or acted upon by gravity only. Some interesting cases are considered in Jacobi's memoir "De Motu puncti singularis" (1842), §§ 6 and 7 (see *post*, No. 108).

98. In the case of a central force varying as (dist.)$^{-2}$, the effect of a resisting medium ($R \propto v^2$) is considered in reference to the lunar theory, in the 'Mécanique Céleste,' Book VII. c. 6. Formulæ for the variations of the elliptic elements are given in the 'Mécanique Analytique,' t. ii. (2nd edition). But the variations of the elliptic elements are fully worked out by means of elliptic and Jacobian functions in Sohncke's valuable memoir "Motus Corporum &c." (1833).

99. The effect of the resistance of the air on a pendulum has been elaborately considered by Poisson, Bessel, Stokes, and others; as the dimensions of the ball are attended to, the problem is in fact a hydrodynamical one.

The effect on the spherical pendulum is considered in Hansen's memoir "Theorie der Pendelbewegung &c." (1853).

The effect on the motion of a projectile is considered in Poisson's memoirs "Sur le Mouvement des Projectiles &c." (1838).

Liouville's *memoirs "Sur quelques Cas particuliers où les équations du mouvement d'un point matériel peuvent s'intégrer"* (1846–49).

100. In the *first* memoir (§ 1) the author considers a point moving in a plane or on a given surface, where the principle of *Vis Viva* holds good (or say where there is a force-function U). The coordinates of the point, and the function U, may be expressed in terms of two variables α, β, and it is assumed that these are such that

$$ds^2=\lambda(d\alpha^2+d\beta^2),$$

where λ is a function of α and β. That is, we have $T=\tfrac{1}{2}\lambda(\alpha'^2+\beta'^2)$; and the equations of motion are

$$\frac{d\,.\,\lambda\alpha'}{dt}=\frac{1}{2}\frac{d\lambda}{d\alpha}(\alpha'^2+\beta'^2)+\frac{dU}{d\alpha},$$

$$\frac{d\,.\,\lambda\beta'}{dt}=\frac{1}{2}\frac{d\lambda}{d\beta}(\alpha'^2+\beta'^2)+\frac{dU}{d\beta}.$$

One integral of these is

$$\lambda(\alpha'^2+\beta'^2)=2U+C\,;$$

and by means of it the equations take the form

$$\frac{d\,.\,\lambda\alpha'}{dt}=\frac{1}{2\lambda}\frac{d\lambda}{d\alpha}(2U+C)+\frac{dU}{d\alpha},$$

$$\frac{d\,.\,\lambda\beta'}{dt}=\frac{1}{2\lambda}\frac{d\lambda}{d\beta}(2U+C)+\frac{dU}{d\beta}.$$

These equations, it is easy to show, may be integrated if

$$(2U+C)\lambda=f\alpha-F\beta,$$

and they then in fact give

$$\lambda^2\alpha'^2=f\alpha-A,$$
$$\lambda^2\beta'^2=A-F\beta,$$

where A is an arbitrary constant. And we then have

$$\frac{d\alpha}{\sqrt{f\alpha-A}}=\frac{d\beta}{\sqrt{A-F\beta}},$$

which gives the path, and the expression for the time is easily obtained by means of a quadrature.

It is not more general, but it is frequently convenient to employ instead of α, β, two variables μ and ν, such that

$$ds^2=\lambda(m\,d\mu^2+n\,d\nu^2),$$

where m is a function of μ only and n of ν only, while λ contains μ and ν. The geometrical signification of the equation $ds^2=\lambda(d\alpha^2+d\beta^2)$, or of the last-mentioned equivalent form, is that the curves

$$\alpha \text{ or } \lambda=\text{const.}, \qquad \beta \text{ or } \mu=\text{const.},$$

intersect at right angles.

The foregoing differential equation of the path, writing $f\mu$, $F\nu$ in the place of $f\alpha$, $F\beta$ respectively, may be expressed in the form

$$f\mu\cos^2 i+F\nu\sin^2 i=A,$$

where i, $90°-i$ are the inclinations of the path at the point (λ, μ) to the two orthotomic curves through this point.

101. The before-mentioned equation

$$(2U+C)\lambda=f\alpha-F\beta$$

may be satisfied independently of C, or else only for a particular value of C. In the former case the law of force is much more restricted, but on the other hand there is no restriction as regards the initial circumstances of the motion; it is the more important one, and is alone attended to in the sequel of the memoir. In the case in question (changing the functional symbols) we must have

$$\lambda=\phi\alpha-\varpi\beta, \quad \lambda U=f\alpha-F\beta;$$

so that the functions denoted above by $f\alpha$, $F\beta$ now are $2f\alpha+C\phi\alpha$, $2F\beta+C\varpi\beta$; the equation of the trajectory is

$$\frac{d\alpha}{\sqrt{2f\alpha+C\phi\alpha-A}}=\frac{d\beta}{\sqrt{A-2F\beta+C\varpi\beta}},$$

and for the *time* the formula is

$$dt=\frac{\phi\alpha\, d\alpha}{\sqrt{2f\alpha+C\phi\alpha-A}}-\frac{\varpi\beta\, d\beta}{\sqrt{A-2F\beta+C\varpi\beta}}.$$

It is noticed also that taking B, ϵ to denote two new arbitrary constants, and writing

$$\Theta=\int d\alpha\sqrt{2f\alpha+C\phi\alpha-A}+\int d\beta\sqrt{A-2F\beta+C\varpi\beta},$$

the equation of the trajectory and the expression for the time assume the forms

$$\frac{d\Theta}{dA}=B, \quad t=2\frac{d\Theta}{dC}+\epsilon,$$

as is known *à priori* by a theorem of Jacobi's.

If the forces vanish, the path is a geodesic line; and denoting by a the ratio of the constants A, C, we have

$$\frac{d\alpha}{\sqrt{\phi\alpha-a}}=\frac{d\beta}{\sqrt{a-\varpi\beta}};$$

and moreover

$$ds=d\alpha\sqrt{\phi\alpha-a}+d\beta\sqrt{a-\phi\beta},$$

which are geometrical properties relating to the geodesic line.

102. Passing to the applications: in the first place, if α, β are rectangular coordinates of a point *in plano*, then writing instead of them x, y, we have $ds^2=dx^2+dy^2$, which is of the required form; but the result obtained is the self-evident one, that the equations may be integrated by quadratures when U is of the form funct. x—funct. y.

But taking instead the elliptic coordinates μ, ν of a point *in plano*,—viz., as employed by the author, these are the semiaxes of the confocal ellipse and hyperbola represented by the equations

$$\frac{x^2}{\mu^2}+\frac{y^2}{\mu^2-b^2}=1,\ \ \frac{x^2}{\nu^2}-\frac{y^2}{b^2-\nu^2}=1,$$

—very interesting results are obtained. The equations give

$$b^2x^2=\mu^2\nu^2,\ \ b^2y^2=(\mu^2-b^2)(b^2-\nu^2),$$

and thence

$$ds^2=(\mu^2-\nu^2)\left(\frac{d\mu^2}{\mu^2-b^2}+\frac{d\nu^2}{\nu^2-b^2}\right),$$

which is of the proper form, and the corresponding expression of U is

$$\mathrm{U}=\frac{f\mu-\mathrm{F}\nu}{\mu^2-\nu^2};$$

so that the force-function having this value ($f\mu$, $\mathrm{F}\nu$ being arbitrary functions of μ and ν respectively), the equations of motion may be integrated by quadratures.

103. In particular, if

$$f\mu=g\mu+g'\mu+k(\mu^4-b^2\mu^2),$$
$$\mathrm{F}\nu=g\nu-g'\nu+k(\nu^4-b^2\nu^2),$$

then

$$\mathrm{U}=\frac{g}{\mu+\nu}+\frac{g'}{\mu-\nu}+k(\mu^2+\nu^2-b^2).$$

But $\mu+\nu$, $\mu-\nu$ are the distances of the point from the two foci, and $\mu^2+\nu^2-b^2(=x^2+y^2)$ is the square of the distance from the centre, so that the expression for U is

$$\mathrm{U}=\frac{g}{r}+\frac{g'}{r'}+k\mathrm{R}^2;$$

and the case is that of forces to the foci varying inversely as the squares of the distances, and a force to the centre varying directly as the distance—the case considered by Lagrange in the problem of two centres. But this is merely one particular case of those given by the general formula.

The cases $g=0$, $g'=0$, $k=0$ (no forces), and $g=0$, $g'=0$ (a force to the centre) lead to some interesting results; it is noticed also that the expression for the force-function may be written $\mathrm{U}=\frac{\text{funct.}(r+r')-\text{funct.}(r-r')}{rr'}$, and that it may be thereby ascertained (without transforming to elliptic coordinates) whether a given value of the force-function is of the form considered in the theory.

In § 3 the author considers the expression $dx^2+dy^2=\lambda(d\alpha^2+d\beta^2)$, λ being in the first instance any function whatever of α and β; and he shows that the expressions of x, y are given by the equation

$$x+y\sqrt{-1}=\psi(\alpha+\beta\sqrt{-1}),$$

ψ being any real function. If, however, it is besides assumed that λ is of the required form$=f\alpha-\mathrm{F}\beta$, then he shows that the system of elliptic coordinates is the only one for which the conditions are satisfied. §§ 4, 5, 6, and 7 relate to the motion of a point on a sphere, an ellipsoid, a surface of revolution, and the skew helicoid respectively; and the concluding § 8 contains only a brief reference to the author's second memoir.

104. Liouville's second and third memoirs may be more briefly noticed. In the *second* memoir the author starts from Jacobi's theorem of the V

function, viz., assuming that there is a force-function U independent of the time, then in order to integrate the equations of motion $\left(\frac{d^2x}{dt^2}=\frac{dU}{dx}, \frac{d^2y}{dt^2}=\frac{dU}{dy}, \frac{d^2z}{dt^2}=\frac{dU}{dz}\right)$, all that is required is to find a function Θ of x, y, z containing three arbitrary constants A, B, C (distinct from the constant attached to Θ by mere addition) satisfying the differential equation

$$\left(\frac{d\Theta}{dx}\right)^2+\left(\frac{d\Theta}{dy}\right)^2+\left(\frac{d\Theta}{dz}\right)^2=2(\mathrm{U}+\mathrm{C});$$

for then the required integrals of the equations of motion are

$$\frac{d\Theta}{d\mathrm{A}}=\mathrm{A}', \frac{d\Theta}{d\mathrm{B}}=\mathrm{B}', \frac{d\Theta}{d\mathrm{C}}=t+\mathrm{C}',$$

A′, B′, C′ being new arbitrary constants. Liouville introduces in place of x, y, z, the elliptic coordinates ρ, μ, ν, which are such that

$$\frac{x^2}{\rho^2}+\frac{y^2}{\rho^2-b^2}+\frac{z^2}{\rho^2-c^2}=1,$$
$$\frac{x^2}{\mu^2}+\frac{y^2}{\mu^2-b^2}-\frac{z^2}{c^2-\mu^2}=1,$$
$$\frac{x^2}{\nu^2}-\frac{y^2}{b^2-\nu^2}-\frac{z^2}{c^2-\nu^2}=1,$$

or, what is the same thing,

$$x=\frac{\rho\mu\nu}{bc},$$
$$y=\frac{\sqrt{\rho^2-b^2}\sqrt{\mu^2-b^2}\sqrt{b^2-\nu^2}}{b\sqrt{c^2-b^2}},$$
$$z=\frac{\sqrt{\rho^2-c^2}\sqrt{c^2-\mu^2}\sqrt{c^2-\nu^2}}{c\sqrt{c^2-b^2}};$$

and he then finds that the resulting partial differential equation in ρ, μ, ν may be integrated provided that U is of the form

$$\mathrm{U}=\frac{(\mu^2-\nu^2)f\rho+(\rho^2-\nu^2)\mathrm{F}\mu+(\rho^2-\nu^2)\varpi\nu}{(\rho^2-\mu^2)(\rho^2-\nu^2)(\mu^2-\nu^2)},$$

f, F, ϖ being any functional symbols whatever: viz., the expression for Θ is

$$\Theta=\int d\rho\sqrt{\frac{2f\rho+\mathrm{A}+\mathrm{B}\rho^2+2\mathrm{C}\rho^4}{(\rho^2-b^2)(\rho^2-c^2)}},$$
$$+\int d\mu\sqrt{\frac{2\mathrm{F}\mu+\mathrm{A}+\mathrm{B}\mu^2+2\mathrm{C}\mu^4}{(\mu^2-b^2)(c^2-\mu^2)}},$$
$$+\int d\nu\sqrt{\frac{2\varpi\nu+\mathrm{A}+\mathrm{B}\nu^2+2\mathrm{C}\nu^4}{(b^2-\nu^2)(c^2-\nu^2)}}.$$

In the case where U=0 we have a particle not acted on by any forces, and the path is of course a straight line. The peculiar form in which these equations are obtained leads to very interesting results in regard to the theory of Abelian integrals, and to that of the geodesic lines of an ellipsoid.

The formulæ require to be modified in certain cases, such as $c=b$ or $b=0$. The case $b=0$ leads to the theory developed in the first memoir in relation to the problem of two centres. The case is indicated where $b=0$, $c=0$, the ratio $b:c$ remaining finite.

The case is briefly considered of a particle moving on a given surface.

105. The *third* memoir purports to relate to a system of particles, but the formulæ are exhibited under a purely analytical point of view; so much so, that the coordinates of the points (3 for each point) are considered as forming a single system of variables $x_1, x_2, \ldots x_i$. The partial differential equation is

$$\left(\frac{d\Theta}{dx_1}\right)^2+\left(\frac{d\Theta}{dx_2}\right)^2\ldots+\left(\frac{d\Theta}{dx_i}\right)^2=2(\mathrm{U}+h),$$

which is transformed by introducing therein the new variables $\rho_1, \rho_2 \ldots \rho_i$ analogous to the elliptic coordinates of the second memoir. The memoir really belongs rather to the theory of the Abelian integrals (in regard to which it appears to be a very valuable one) than to dynamics.

Memoirs by Jacobi, Bertrand, *and* Donkin, *relating to various Special Problems.*

106. I have inserted this heading for the sake of showing at a single view what are the special problems incidentally considered in the under-mentioned memoirs which are referred to in several places in the present Report.

107. Jacobi, "De Motu puncti singularis" (1842).—I call to mind that the memoir chiefly depends on the theorem of the Ultimate Multiplier (the theory in its generality being developed in the later memoir "Theoria Novi Multiplicatoris &c.," 1844–45). § 4 is entitled "The motion of a point on the surface of revolution," which, the principle of the conservation of areas holding good, is reduced to the problem of the motion on the meridian curve, and thus depends upon quadratures only. § 5 is entitled "On the motion of a point about a fixed centre attracted according to a certain law more general than the Newtonian one" (*antè*, No. 85). § 6. "On the motion of a point on a given curve and in a resisting medium" (resistance$=a+be^{cv^2}$, or$=a+bv^2$); and § 7. "On the Ballistic Curve," viz., the forces are gravity and a resistance$=a+bv^n$.

108. In Jacobi's memoir "Theoria Novi Multiplicatoris &c." (1845), § 25 is entitled "On the motion of a point attracted towards a fixed centre" (see *antè*, No. 87); § 26. "On the motion of a point attracted towards two fixed centres according to the Newtonian law" (*antè*, No. 56); § 27. "On the rotation of a solid body about a fixed point" (*post*, No. 193); § 28. "On the problem of three bodies moving in a right line; the Eulerian substitution; theorems on homogeneous forces" (*antè*, No. 91); and § 29, "The principle of the ultimate multiplier applied to a free system of material points moving in a resisting medium; on the motion of a comet in a resisting medium about the sun."

109. And in Jacobi's memoir "Nova Methodus &c." (1862), besides § 64 and § 65, which are applications of the method to general dynamical theorems, we have § 66, containing a simultaneous solution of the problem of the motion of a point attracted to a fixed centre and of that of the rotation of a solid body (*post*, No. 206), and § 67, relating to the motion of a point attracted to a fixed centre according to the Newtonian law.

110. Bertrand's "Mémoire sur les intégrales différentielles de la Mécanique" (1852).—§ III. relates to the motion of a point attracted to a fixed centre by a force varying as a function of the distance; § IV. to the case where the forces arise from a force-function $\mathrm{U}=\frac{1}{x^2+y^2}\phi\left(\frac{x}{y}\right)$ (or, what is the same thing,

$=\frac{\Phi}{r^2}\Big)$ (*antè*, No. 87); § V. to the problem of two centres (*antè*, No. 62), and § VI. to the problem of three bodies (*post*, No. 117).

111. Donkin's memoir "On a Class of Differential Equations &c." (1855). Part I. Nos. 27 to 30 relate to the problem of central forces (in space), No. 31 to the rotation of a solid body, and § III. to the same subject, viz. Nos. 40 and 41 to the general case, Nos. 42 to 44 to the particular case A=B; and Nos. 45 to 48 to the reduction thereto of the general case by treating the forces which arise from the inequality of A and B as disturbing forces. Part II. Nos. 59 and 60 relate to the spherical pendulum; Nos. 72 and 73 to "Transformation from fixed to moving axes of coordinates," say to Relative Motion; and Nos. 84 to 96 to the problem of three bodies (*post*, No. 120).

The Problem of Three Bodies, Article Nos. 112 to 123.

112. A system of differential equations, such as

$$\frac{dx_1}{X_1}=\frac{dx_2}{X_2}\cdots=\frac{dx_{n+1}}{X_{n+1}}$$

(n equations between $\overline{n+1}$ variables), may be termed a system of the nth order, or more simply a system of n equations. Let $(u_1, u_2 \ldots . u_{n+1})$ be any functions of the original variables $(x_1, x_2, \ldots . x_{n+1})$, the system may be transformed into the similar system

$$\frac{du_1}{U_1}=\frac{du_2}{U_2}\cdots=\frac{du_{n+1}}{U_{n+1}};$$

and if it happens that we have *e.g.* U_1 identically equal to zero, then the system becomes

$$du_1=0, \left(\frac{du_2}{U_2}=\frac{du_3}{U_3}\cdots=\frac{du_{n+1}}{U_{n+1}}\right),$$

so that we have an integral $u_1=c$, and then in the remaining equations substituting this value, or treating u_1 as constant, the system is reduced to one of $(m-1)$ equations. Or again, if it happen that we have in the transformed system m equations $(m<n)$, say

$$\frac{du_1}{U_1}=\frac{du_2}{U_2}\cdots=\frac{du_{m+1}}{U_{m+1}},$$

which are such that $U_1, U_2 \ldots U_{m+1}$ are functions of only the $m+1$ variables $u_1, u_2 \ldots u_{m+1}$, then the integration of the proposed system of n equations depends on the integration in the first instance of a system of m equations. It is to be observed that if the system of m equations can be integrated, then the completion of the integration of the original system depends on the integration of a system of $n-m$ equations, and in this sense the original system of n equations may be said to be broken up into two systems of m equations and $n-m$ equations respectively: but *non constat* that the system of m equations admits of integration; and it is therefore more correct to say that, from the original system of the n equations, there has been *separated off* a system of m equations.

113. The bearing of the foregoing remarks on the problem of three bodies will presently appear. It will be seen that whereas the problem as it stood before Jacobi depends on a system of *seven* equations, it has been shown by him that there may be separated off from this a system of *six* equations.

114. Jacobi's memoir "Sur l'élimination des Nœuds &c." (1843).—The problem of the motion of three mutually attracting bodies is in the first instance reduced to that of the motion of two fictitious bodies (which may be considered as mutually attracting bodies, attracted by a fixed centre of force)*. In fact, in the original problem the centre of gravity of the three bodies moves uniformly in a right line, and it may without any real loss of generality be taken to be at rest; that is, if the x-coordinates of the three bodies are ξ_1, ξ_2, ξ_3, then $m_1\xi_1+m_2\xi_2+m_3\xi_3=0$, or ξ_1, ξ_2, ξ_3 may be taken to be linear functions of two quantities x_1 and x_2. And similarly for the y-coordinates and the z-coordinates respectively. And (x_1, y_1, z_1), (x_2, y_2, z_2) may be regarded as the coordinates of two bodies revolving about a fixed centre of force. Hence representing the differential coefficients in regard to the time by x_1', &c., and treating these as new variables, the equations of motion will assume the form

$$\frac{dx_1}{x_1'}=\frac{dy_1}{y_1'}=\frac{dz_1}{z_1'}=\frac{dx_2}{x_2'}=\frac{dy_2}{y_2'}=\frac{dz_2}{z_2'}$$

$$=\frac{dx_1'}{X_1}=\frac{dy_1'}{Y_1}=\frac{dz_1'}{Z_1}=\frac{dx_2'}{X_2}=\frac{dy_2'}{Y_2}=\frac{dz_2'}{Z_2}(=dt),$$

where X_1, Y_1, Z_1, X_2, Y_2, Z_2 are forces capable of representation by means of a force-function U. This is a system of twelve equations; but since X_1, Y_1, Z_1, X_2, Y_2, Z_2 are independent of the time, we may omit the equation $(=dt)$, and treat the system as one of eleven equations between the variables x_1, y_1, z_1, x_2, y_2, z_2, x_1', y_1', z_1', x_2', y_2', z_2': if this system were integrated, the determination of the time would then depend on a quadrature only. But for the system of eleven equations we have four integrals, viz., the integral of *Vis Viva* and the three integrals of areas, and the system is thus reducible to one of $(11-4=)$ seven equations. This preliminary transformation in Jacobi's memoir explains the remark that the problem, as it stood before him, depended on a system of seven equations.

115. Jacobi remarks that in the transformed problem the three integrals of areas show (1) that the intersection of the planes of the orbits of the two bodies lie in a fixed plane, the invariable plane of the system; (2) that the inclinations of the planes of the two orbits to this fixed plane, and the parameters of the two orbits considered as variable ellipses, are four elements any two of which rigorously determine the two others.

And then choosing for variables the inclinations of the two orbits to the invariable plane, the two radius vectors, the angles which they form with the intersection of the planes of the two orbits, and lastly the angle between this intersection (being as already mentioned a line in the invariable plane) with a fixed line in the invariable plane, he finds *that the last-mentioned angle entirely disappears from the system of differential equations, and is determined after their integration by a quadrature.* In this new form of the differential equations there is no trace of the nodes. The differential equations which determine the relative motion of the three bodies are reduced to five equations of the first order and one of the second order. The equations in question are the equations I. to VI. given at the end of the memoir. It is to be remarked that the differential dt is not eliminated from these equations; the last of them is $\frac{d^2}{dt^2}(\mu r^2+\mu_1 r_1^2)=2U-2h$; and if to reduce them to a system of equa-

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* This is the effect of Jacobi's reduction; but the explicit statement of the theorem, and actual replacement of the problem of the three bodies by that of the two bodies attracted to a fixed centre, is due to Bertrand (*post*, No. 117).

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tions of the first order we write $\frac{d}{dt}(\mu r^2+\mu_1 r_1{}^2)=\theta$, and therefore $\frac{d\theta}{dt}=2\mathrm{U}-2h$, the system may be presented in the form

$$\frac{du}{\mathrm{U}}=\frac{du_1}{\mathrm{U}_1}=\frac{di}{\mathrm{I}}=\frac{di_1}{\mathrm{I}_1}=\frac{dr}{\mathrm{R}}=\frac{dr_1}{\mathrm{R}_1}=\frac{d\theta}{\Theta}(=dt),$$

which if we do, and then omit the equation $(=dt)$, we have a system of six equations between the seven quantities $u, u_1, i, i_1, r, r_1, \theta$; when this is integrated, the equation $(=dt)$ gives the time by a quadrature; and finally, Jacobi's equation VII. $\left(d\Omega=\tan u\frac{di}{\sin i}\right)$ gives by a quadrature the angle before referred to as disappearing from the system of equations I. to VI.

116. But when Jacobi says, "Par suite on a fait cinq intégrations. Les intégrales connues n'étant qu'au nombre de quatre, on pourra donc dire que l'on a fait une intégration de plus dans le système du monde. Je dis dans le système du monde puisque la même méthode s'appliqué à un nombre quelconque de corps," the language used is not, I think, quite accurate. It, in fact, appears from the memoir that it is only on the assumption of the integration of the system of six equations that, besides the integral of *Vis Viva* and the integrals of areas, the remaining two integrals are known; in fact, after, but not before the system of the order six has been integrated, the time t and the angle Ω are each of them given by a quadrature.

117. Bertrand's "Mémoire sur l'intégration des équations différentielles de la Mécanique" (1852).—I have spoken of this memoir in No. 56 of my former Report. The course of investigation is the inquiry as to the integrals, which, combined according to Poisson's theorem with the integral of *Vis Viva* or any other given integral, give rise to an illusory result. But as regards the application made to the problem of three bodies, it will be more convenient to state from a different point of view the conclusions arrived at: and I may mention that when the author says "Je parviens . . à reduire la question à l'intégration de six équations tout du premier ordre, c'est-à-dire que j'effectue une intégration de plus que ne l'avait fait Jacobi," he seems to have overlooked that Jacobi's system of five equations of the first order and one of the second order really is, as above noticed, a system of the six equations with another equation which then gives the time by a quadrature, and that, at least as appears to me, he has not advanced the solution beyond the point to which it had been carried by Jacobi*.

118. Presenting Bertrand's results in the slightly different notation in which they are reproduced in Bour's memoir (*post*, No. 122), then if (x, y, z), (x_1, y_1, z_1) are the coordinates of the two bodies (the problem actually considered being, as by Jacobi, that of the motion of two bodies about a fixed centre of force), and representing the functions $x^2+y^2+z^2$, $x_1{}^2+y_1{}^2+z_1{}^2$, $m^2(x'^2+y'^2+z'^2)$, $m_1{}^2(x_1{}'^2+y_1{}'^2+z_1{}'^2)$, $m(xx'+yy'+zz')$, $m_1(x_1x_1{}'+y_1y_1{}'+z_1z_1{}')$, $m(x_1x'+y_1y'+z_1z')$, $m_1(xx_1{}'+yy_1{}'+zz_1{}')$, $(xx_1+yy_1+zz_1)$ $mm_1(x'x_1{}'+y'y_1{}'+z'z'_1)$ by $u, u_1, v, v_1, w, w_1, r, r_1, q, s$ respectively, then the last-mentioned quantities are connected by a single geometrical relation, so that any one of them, say s, may be considered as a given function of the remaining nine. And the author *in effect* shows that the equations of motion give a system

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* These remarks were communicated by me to M. Bertrand—see my letter "Sur l'intégration des équations différentielles de la Mécanique," Comptes Rendus (1863)—and, in the answer he kindly sent me, he agrees that they are correct.

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$$\frac{du}{U}=\frac{du_1}{U_1}=\frac{dv}{V}=\frac{dv_1}{V_1}=\frac{dw}{W}=\frac{dw_1}{W_1}=\frac{dr}{R}=\frac{dr_1}{R_1}=\frac{dq}{Q}=(dt),$$

where U, U_1, &c. are functions of the quantities u, u_1, v, &c. Omitting from the system the equation $(=dt)$, there are eight equations between nine quantities; but there are two known integrals, viz., the integral of *Vis Viva* and the integral of principal moment (or sum of the squares of the integrals of areas); that is to say, the system is really a system of *six* equations.

119. Painvin, "Recherche du dernier Multiplicateur &c." (1854).—The author investigates the ultimate multiplier for two systems of differential equations:—

1°. The system of the equations I. to VI. in Jacobi's memoir "Sur l'élimination des Nœuds &c." (*antè*, No. 114). Writing in the equations $\frac{dr}{dt}=r'$, $\frac{dr_1}{dt}=r_1'$, and treating r', r_1' as new variables, the system may be written in the form

$$\frac{du}{U}=\frac{du_1}{U_1}=\frac{di}{I}=\frac{di_1}{I_1}=\frac{dr}{R}=\frac{dr_1}{R_1}=\frac{dr'}{R'}=\frac{dr_1'}{R_1'}(=dt),$$

which, omitting the equation $(=dt)$, is a system of seven equations between eight variables; and it is for this form of the system that the value of M is determined, the result obtained being the simple and elegant one, $M=\frac{\sin i \sin i_1}{\sin^2 I}$. The system of seven equations has an integral which is in fact the equation V. of the system in Jacobi's form, so that it is really a system of *six* equations (*antè*, No. 115).

2°. The system secondly discussed is Bertrand's system of nine equations (*antè*, No. 118). The multiplier M is obtained under four different forms, $M=\frac{1}{\sqrt{B^2-AC}}=\frac{1}{\sqrt{\alpha\alpha_1}}=\frac{1}{AZ+B}=\frac{1}{mn}$ (I do not stop to explain the notation), the last of them being referred to as a result announced by M. Bertrand in his course. But it is shown by M. Bour in the memoir next referred to (*post*, No. 122), that the multiplier for the system in question can be obtained in a very much more simple manner, almost without calculation.

120. In connexion with Jacobi's theory of the elimination of the Nodes, I may refer to the investigations "Application to the Problem of three Bodies" Nos. 84 to 96 of Donkin's memoir "On a Class of Differential Equations &c." Part II. The author remarks that his differential equations No. 93 afford an example of the so-called elimination of the Nodes, quite different however (in that they are *merely* transformations of the original differential equations of the problem without any integrations) from that effected by Jacobi.

121. It may be right to refer again in this place to the concluding part of § 28 of Jacobi's memoir "Nova Theoria Multiplicatoris" (*antè*, No. 92), as bearing on the problem of three bodies.

122. Bour's "Mémoire sur le Problème des Trois Corps" (1856).—The author remarks that Bertrand's system of equations have lost the remarkable form and the properties which characterize the ordinary equations for the solution of a dynamical problem. But by selecting eight new variables, functions of Bertrand's variables, the system may be brought back to the standard Hamiltonian form

$$\frac{dq_i}{dt}=\frac{dH}{dp_i},\ \frac{dp_i}{dt}=-\frac{dH}{dq_i},$$

or to the form adopted by M. Bour, of a partial differential equation

$$\Sigma\left(\frac{d\mathrm{H}}{dq_i}\frac{d\zeta}{dp_i}-\frac{d\mathrm{H}}{dp_i}\frac{d\zeta}{dq_i}\right)=0\,;$$

and guiding himself by a theorem in relation to canonical integrals obtained in his memoir of 1855 (see No. 66 of my former Report), he finds by a somewhat intricate analysis the expressions of the eight new variables $p_1, p_2, p_3, p_4, q_1, q_2, q_3, q_4$. The results ultimately obtained are of a very remarkable and interesting form, viz. $\mathrm{H}=$funct. $(p_1, p_2, p_3, p_4, q_1, q_2, q_3, q_4)$ is equal to the value it would have for motion in a plane, *plus* a term admitting of a simple geometrical interpretation, and he thus arrives at the following theorem as a *résumé* of the whole memoir, viz.,

"In order to integrate in the general case the problem of three bodies, it is sufficient to solve the case of motion in a plane, and then to take account of a disturbing function equal to the product of a constant depending on the areas by the sum of the moments of inertia of the bodies round a certain axis, divided by the square of the triangle formed by the three bodies."

123. It may be remarked that the only given integral of the system of eight equations is the integral of *Vis Viva*, $\mathrm{H}=$const., and that using this equation to eliminate one of the variables, and omitting the equation $(=dt)$, we have, as in the solutions of Jacobi and Bertrand, a system of six equations between seven variables. As the equations are in the standard dynamical form, no investigation is needed of the multiplier M, which is given by Jacobi's general theory, and consequently when any five integrals of the six equations are given, the remaining integral can be obtained by a quadrature.

In the case of three bodies moving in a plane, the solution takes a very simple form, which is given in the concluding paragraph of the memoir.

Transformation of Coordinates, Articles Nos. 124 to 141.

124. It may be convenient to remark at once that two sets of rectangular coordinates may be related to each other properly or improperly, viz., the axes to which they belong (considered as drawn from the origin in the positive directions) may be either capable or else incapable of being brought into coincidence. The latter relation, although of equal generality with the former one, may for the most part be disregarded; for by merely reversing the directions of the one set of axes, the improper is converted into the proper relation.

125. In the memoir "Problema Algebraicum &c." (1770) Euler proposes to himself the question "Invenire novem numeros ita in quadratum disponendos

A, B, C
D, E, F
G, H, I

ut satisfiat duodecem sequentibus conditionibus," &c., viz., substituting for A, B, C, &c. the ordinary letters

$$\begin{array}{ccc}\alpha, & \beta, & \gamma,\\ \alpha', & \beta', & \gamma',\\ \alpha'', & \beta'', & \gamma'',\end{array}$$

the twelve conditions are

$$\begin{array}{ll}\alpha^2\ +\alpha'^2\ +\alpha''^2=1, & \alpha\beta+\alpha'\beta'+\alpha''\beta''=0,\\ \beta^2\ +\beta'^2\ +\beta''^2=1, & \beta\gamma+\beta'\gamma'+\beta''\gamma''=0,\\ \gamma^2\ +\gamma'^2\ +\gamma''^2=1, & \gamma\alpha+\gamma'\alpha'+\gamma''\alpha''=0,\end{array}$$

$$\begin{array}{ll}\alpha^2\ +\beta^2\ +\gamma^2\ =1, & \alpha\alpha'\ +\beta\beta'\ +\gamma\gamma'\ =0,\\ \alpha'^2\ +\beta'^2\ +\gamma'^2=1, & \alpha'\alpha''\quad\beta'\beta''+\gamma'\gamma''=0,\\ \alpha''^2+\beta''^2+\gamma''^2=1, & \alpha\alpha''\ +\beta''\beta\ +\gamma''\gamma=0.\end{array}$$

And he remarks that this is in fact the problem of the transformation of coordinates, viz., if we have

$$\begin{aligned} X &= \alpha x + \beta y + \gamma z, \\ Y &= \alpha' x + \beta' y + \gamma' z, \\ Z &= \alpha'' x + \beta'' y + \gamma'' z, \end{aligned}$$

then the first equations are such as to give identically

$$X^2 + Y^2 + Z^2 = x^2 + y^2 + z^2.$$

126. Assuming the first six equations, he shows by a direct analytical process that $\alpha^2 = (\beta'\gamma'' - \beta''\gamma')^2$, or $\alpha = \pm(\beta'\gamma'' - \beta''\gamma')$; or taking the positive sign (for, as the numbers may be taken as well positively as negatively, there is nothing lost by doing so) $\alpha = \beta'\gamma'' - \beta''\gamma'$, which gives the system

$$\begin{array}{lll} \alpha = \beta'\gamma'' - \beta''\gamma', & \beta = \gamma'\alpha'' - \gamma''\alpha', & \gamma = \alpha'\beta'' - \alpha''\beta', \\ \alpha' = \beta''\gamma - \beta\gamma'', & \beta' = \gamma''\alpha - \gamma\alpha'', & \gamma' = \alpha''\beta - \alpha\beta'', \\ \alpha'' = \beta\gamma' - \beta'\gamma, & \beta'' = \gamma\alpha' - \gamma'\alpha, & \gamma'' = \alpha\beta' - \alpha'\beta, \end{array}$$

and from these he deduces the second system of six equations. The inverse system of equations

$$\begin{aligned} X &= \alpha x + \alpha' y + \alpha'' z, \\ Y &= \beta x + \beta' y + \beta'' z, \\ Z &= \gamma x + \gamma' y + \gamma'' z \end{aligned}$$

is not explicitly referred to.

127. He then satisfies the equations by means of trigonometrical substitutions, viz., assuming $\alpha = \cos\zeta$, then $\alpha'^2 + \alpha''^2 = \sin^2\zeta$, which is satisfied by $\alpha' = \sin\zeta\cos\eta$, $\alpha'' = \sin\zeta\sin\eta$, &c., and he thus obtains for the coefficients a set of values involving the angles ζ, η, θ, which are the same as those mentioned *post*, No. 130. And he shows how these formulæ may be obtained geometrically by three successive transformations of two coordinates only. The remainder of the memoir relates to the analogous problem of the transformation of four or more coordinates.

128. I have analysed so much of Euler's memoir in order to show that it contains nearly the whole of the ordinary theory of the transformation of coordinates; the only addition required is the equation

$$\begin{vmatrix} \alpha, & \beta, & \gamma \\ \alpha', & \beta', & \gamma' \\ \alpha'', & \beta'', & \gamma'' \end{vmatrix} = \pm 1,$$

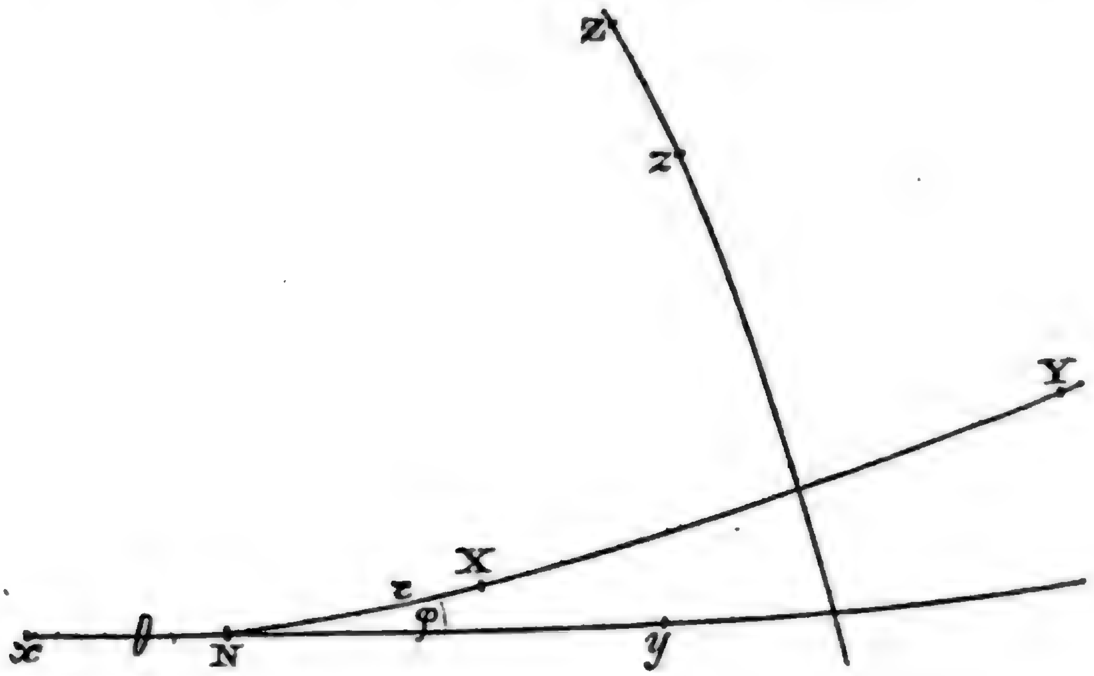
where the sign + gives $\alpha = \beta'\gamma'' - \beta''\gamma'$, &c. (*ut supra*), but the sign − would give $\alpha = -(\beta'\gamma'' - \beta''\gamma')$, &c.

129. The distinction of the ambiguous sign is in fact the above-mentioned one of the proper and improper transformations; viz., for the sign + the two sets of axes can, for the sign − they cannot, be brought into coincidence: this very important remark was, I believe, first made by Jacobi in one of his early memoirs in Crelle's Journal, but I have lost the reference. As already mentioned, it is allowable to attend only to the proper transformation, and to consider the value of the determinant as being $= +1$; and this is in fact almost always done.

130. Euler's formulæ involving the three angles are those which are ordinarily made use of in the problem of rotation and the problems of physical astronomy generally.

It is convenient to take them as in the figure, viz., θ, the longitude of node,

ϕ, the inclination, τ, the angular distance of X from node, and the formulæ



of transformation then are

	X	Y	Z
x	$\cos\tau\cos\theta-\sin\tau\sin\theta\cos\phi$	$-\sin\tau\cos\theta-\cos\tau\sin\theta\cos\phi$	$\sin\theta\sin\phi$
y	$\cos\tau\sin\theta+\sin\tau\cos\theta\cos\phi$	$-\sin\tau\sin\theta+\cos\tau\cos\theta\cos\phi$	$-\cos\theta\sin\phi$
z	$\sin\tau\sin\phi$	$\cos\tau\sin\phi$	$\cos\phi$

The foregoing very convenient algorithm, viz., the employment of

	X	Y	Z
x	α	β	γ
y	α'	β'	γ'
z	α''	β''	γ''

to denote the system of equations

$$\begin{aligned} x&=\alpha X+\beta Y+\gamma Z,\\ y&=\alpha' X+\beta' Y+\gamma' Z,\\ z&=\alpha'' X+\beta'' Y+\gamma'' Z, \end{aligned}$$

is due to M. Lamé.

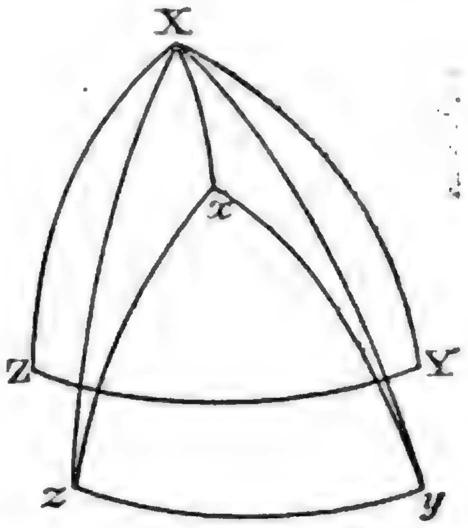
131. But previously to the foregoing investigations, viz., in the memoir "Du Mouvement de Rotation &c.," Mém. de Berlin for 1758 (pr. 1765), Euler had obtained incidentally a very elegant solution of the problem of the transformation of coordinates; this is in fact identical with the next mentioned one, the letters l, m, n; λ, μ, ν being used in the place of ζ, ζ', ζ''; η, η', η''.

132. In the memoir "Formulæ generales pro translatione &c." (1775), Euler gives the following formulæ for the transformation of coordinates, viz., if the position of the set of axes XYZ in reference to the set xyz is determined by

$$xX;\ yX,\ zX = 90^\circ - \zeta,\ 90^\circ - \zeta',\ 90^\circ - \zeta'',$$

$$\angle^{s}\ YXx,\ YXy,\ YXz = \eta,\ \eta',\ \eta'',$$

then the formulæ of transformation are



	X	Y	Z
x	$\sin\zeta$	$\cos\zeta\ \ \sin\eta$	$\cos\zeta\ \ \cos\eta$
y	$\sin\zeta'$	$\cos\zeta'\ \ \sin\eta'$	$\cos\zeta'\ \ \cos\eta'$
z	$\sin\zeta''$	$\cos\zeta''\ \sin\eta''$	$\cos\zeta''\ \cos\eta''$

with the following equations connecting the six angles, viz., if

$$-\Delta^2 = \cos(\eta' - \eta'')\cos(\eta'' - \eta)\cos(\eta - \eta'),$$

then

$$\tan\zeta = \frac{-\Delta}{\cos(\eta' - \eta'')},\quad \tan\zeta' = \frac{-\Delta}{\cos(\eta'' - \eta)},\quad \tan\zeta'' = \frac{-\Delta}{\cos(\eta - \eta')}.$$

133. It is right to notice that these values of ζ, ζ', ζ'' give the twelve equations $\alpha^2 + \beta^2 + \gamma^2 = 1$, &c., but they do not give definitely $\alpha = \beta'\gamma'' - \beta''\gamma'$, &c., but only $\alpha = \pm(\beta'\gamma'' - \beta''\gamma')$; that is, in the formulæ in question the two sets of axes are not of necessity displacements the one of the other. In the same memoir Euler considers two sets of rectangular axes, and assuming that they are displacements the one of the other (this assumption is not made as explicitly as it should have been), he remarks that the one set may be made to coincide with the other set by means of a finite rotation about a certain axis (which may conveniently be termed the Resultant Axis). This consideration leads him to an equation which ought to be satisfied by the coefficients of transformation, but which he is not able to verify by means of the foregoing expressions in terms of $\zeta, \zeta', \zeta'', \eta, \eta', \eta''$.

134. I remark that Euler's equation in fact is

$$\begin{vmatrix} \alpha - 1, & \beta & , \gamma \\ \alpha' & , \beta' - 1, & \gamma' \\ \alpha'' & , \beta'' & , \gamma'' - 1 \end{vmatrix} = 0,$$

or, as it may be written,

$$\begin{vmatrix} \alpha, & \beta, & \gamma \\ \alpha', & \beta', & \gamma' \\ \alpha'', & \beta'', & \gamma'' \end{vmatrix} - (\beta'\gamma'' - \beta''\gamma') - (\gamma''\alpha - \gamma\alpha'') - (\alpha\beta' - \alpha'\beta) + \alpha + \beta' + \gamma'' - 1 = 0,$$

in which form it is an immediate consequence of the equations

$$\begin{vmatrix} \alpha, & \beta, & \gamma \\ \alpha', & \beta', & \gamma' \\ \alpha'', & \beta'', & \gamma'' \end{vmatrix} = 1,\ \alpha = \beta'\gamma'' - \beta''\gamma',\ \&c.,$$

which are true for the proper, but not for the improper transformation.

135. In the undated addition to the memoir, Euler states the theorem of the resultant axis as follows:—"Theorema. Quomodocunque sphæra circa centrum suum convertatur, semper assignari potest diameter cujus directio in situ translato conveniat cum situ originali;" and he again endeavours to obtain a verification of the foregoing analytical theorem.

136. The theory of the Resultant Axis was further developed by Euler in the memoir "Nova Methodus Motum &c." (1775), and by Lexell in the me-

moir "Nonnulla theoremata generalia &c." (1775): the geometrical investigations are given more completely and in greater detail in Lexell's memoir. The result is contained in the following system of formulæ for the transformation of coordinates, viz., if α, β, γ are the inclinations of the resultant axis to the original set, and if ϕ is the rotation about the resultant axis, or say the resultant rotation, then we have

	X	Y	Z
x	$\cos^2\alpha+\sin^2\alpha\cos\phi$	$\cos\alpha\cos\beta(1-\cos\phi)+\cos\gamma\sin\phi$	$\cos\alpha\cos\gamma(1-\cos\phi)-\cos\beta\sin\phi$
y	$\cos\beta\cos\alpha(1-\cos\phi)-\cos\gamma\sin\phi$	$\cos^2\beta+\sin^2\beta\cos\phi$	$\cos\beta\cos\gamma(1-\cos\phi)+\cos\alpha\sin\phi$
z	$\cos\gamma\cos\alpha(1-\cos\phi)+\cos\beta\sin\phi$	$\cos\gamma\cos\beta(1-\cos\phi)-\cos\alpha\sin\phi$	$\cos^2\gamma+\sin^2\gamma\cos\phi$

Euler attempts, but not very successfully, to apply the formulæ to the dynamical problem of the rotation of a solid body: he does not introduce them into the differential equations, but only into the integral ones, and his results are complicated and inelegant. The further simplification effected by Rodrigues was in fact required.

137. Jacobi's paper, "Euleri formulæ &c." (1827), merely cites the last-mentioned result.

138. I find it stated in Lacroix's 'Differential Calculus,' t. i. p. 533, that the following system for the transformation of coordinates was obtained by Monge (no reference is given in Lacroix), viz., the system being as above,

$$\begin{vmatrix} \alpha\ , & \beta\ , & \gamma\ , \\ \alpha'\ , & \beta'\ , & \gamma'\ , \\ \alpha''\ , & \beta''\ , & \gamma''\ , \end{vmatrix}$$

and the quantities α, β', γ'' being arbitrary, then putting

$$\begin{aligned} 1+\alpha+\beta'+\gamma''&=\mathrm{M}, \\ 1+\alpha-\beta'-\gamma''&=\mathrm{N}, \\ 1-\alpha+\beta'-\gamma''&=\mathrm{P}, \\ 1-\alpha-\beta'+\gamma''&=\mathrm{Q}, \end{aligned}$$

so that

$$\mathrm{M}+\mathrm{N}+\mathrm{P}+\mathrm{Q}=4,$$

we have

$$2\beta=\sqrt{\mathrm{NP}}+\sqrt{\mathrm{MQ}},\ 2\gamma'=\sqrt{\mathrm{PQ}}+\sqrt{\mathrm{MN}},\ 2\alpha''=\sqrt{\mathrm{QN}}+\sqrt{\mathrm{MP}},$$

$$2\alpha'=\sqrt{\mathrm{NP}}-\sqrt{\mathrm{MQ}},\ 2\beta''=\sqrt{\mathrm{PQ}}-\sqrt{\mathrm{MN}},\ 2\gamma\ =\sqrt{\mathrm{QN}}-\sqrt{\mathrm{MP}}.$$

These are formulæ very closely connected with those of Rodrigues.

139. The theory was perfected by Rodrigues in the valuable memoir "Des lois géométriques &c." (1840). Using for greater convenience λ, μ, ν in the place of his $\tfrac{1}{2}m$, $\tfrac{1}{2}n$, $\tfrac{1}{2}p$, he in effect writes

$$\begin{aligned} \tan\tfrac{1}{2}\phi\ \cos\alpha&=\lambda, \\ \tan\tfrac{1}{2}\phi\ \cos\beta&=\mu, \\ \tan\tfrac{1}{2}\phi\ \cos\gamma&=\nu, \end{aligned}$$

and this being so, the coefficients of transformation are

$$\begin{array}{lll} 1+\lambda^2-\mu^2-\nu^2, & 2(\lambda\mu+\nu) \quad , & 2(\lambda\nu-\mu) \quad , \\ 2(\mu\lambda-\nu) \quad , & 1-\lambda^2+\mu^2-\nu^2, & 2(\mu\nu+\lambda) \quad , \\ 2(\nu\lambda+\mu) \quad , & 2\nu\mu-\lambda \quad , & 1-\lambda^2-\mu^2+\nu^2, \end{array}$$

all divided by the common denominator $1+\lambda^2+\mu^2+\nu^2$. Conversely, if the coefficients of transformation are as usual represented by

$$\begin{array}{l} \alpha\ ,\ \beta\ ,\ \gamma\ , \\ \alpha'\ ,\ \beta'\ ,\ \gamma'\ , \\ \alpha'',\ \beta'',\ \gamma'', \end{array}$$

then λ^2, μ^2, ν^2, λ, μ, ν are respectively equal to

$$\begin{array}{lll} 1+\alpha-\beta'-\gamma'', & 1-\alpha+\beta'-\gamma'', & 1-\alpha-\beta'+\gamma'', \\ \gamma'-\beta'' \quad , & \alpha''-\beta \quad , & \beta-\alpha' \quad , \end{array}$$

each of them divided by $1+\alpha+\beta'+\gamma''$.

The memoir contains very elegant formulæ for the composition of finite rotations, and it will be again referred to in speaking of the kinematics of a solid body.

140. Sir W. R. Hamilton's first papers on the theory of quaternions were published in the years 1843 and 1844: the fundamental idea consists in the employment of the imaginaries i, j, k, which are such that

$$i^2=j^2=k^2=-1,\ jk=-kj=i,\ ki=-ik=j,\ ij=-ji=k,$$

whence also

$$\begin{aligned} (w+ix+jy+kz)(w'+ix'+jy'+kz') \\ = ww'-xx'-yy'-zz' \\ +i(wx'+w'x+yz'-y'z) \\ +j(wy'+w'y+zx'-z'x) \\ +k(wz'+w'z+xy'-xy)\ ; \end{aligned}$$

so that representing the right-hand side by

$$W+iX+jY+kZ,$$

we have identically

$$W^2+X^2+Y^2+Z^2=(w^2+x^2+y^2+z^2)(w'^2+x'^2+y'^2+z'^2).$$

It is hardly necessary to remark that Sir W. R. Hamilton in his various publications on the subject, and in the 'Lectures on Quaternions,' Dublin, 1853, has developed the theory in detail, and has made the most interesting applications of it to geometrical and dynamical questions; and although the first explicit application of it to the present question may have been made in my own paper next referred to, it seems clear that the whole theory was in its original conception intimately connected with the notion of rotation.

141. Cayley, "On certain Results relating to Quaternions" (1845).—It is shown that Rodrigues' transformation formula may be expressed in a very simple manner by means of quaternions; viz., we have

$$ix+jy+kz=(1+i\lambda+j\mu+k\nu)^{-1}(iX+jY+kZ)(1+i\lambda+j\mu+k\nu),$$

where developing the function on the right-hand side, and equating the coefficients of i, j, k, we obtain the formulæ in question. A subsequent paper, Cayley, "On the application of Quaternions to the Theory of Rotation" (1848), relates to the composition of rotations.

Principal Axes, and Moments of Inertia. Article Nos. 142–163.

142. The theorem of principal axes consists herein, that at any point of a solid body there exists a system of axes Ox, Oy, Oz, such that

$$\int yzdm=0,\ \int zxdm=0,\ \int xydm=0.$$

But this, the original form of the theorem, is a mere deduction from a general theory of the representation of the integrals

$$\int x^2 dm,\ \int y^2 dm,\ \int z^2 dm,\ \int yz dm,\ \int zx dm,\ \int xy dm$$

for any axes through the given origin by means of an ellipsoid depending on the values of these integrals corresponding to a given set of rectangular axes through the same origin.

143. If, for convenience, we write as follows, $M=\int dm$ the mass of the body, and

$$A'=\int x^2 dm,\ B'=\int y^2 dm,\ C'=\int z^2 dm,\ F'=\int yz dm,\ G'=\int zx dm,\ H'=\int xy dm,$$

and moreover

$$A=\int (y^2+z^2)\, dm,\ B=\int (z^2+x^2)\, dm,\ C=\int (x^2+y^2)\, dm,$$
$$F=-\int yz dm,\ G=-\int zx dm,\ H=-\int xy dm^*,$$

so that

$$A=B'+C',\ B=C'+A',\ C=A'+B',\ F=-F',\ G=-G',\ H=-H',$$

then the ellipsoid which in the first instance presents itself for this purpose, and which Prof. Price has termed the Ellipsoid of Principal Axes, but which I would rather term the "Comomental Ellipsoid," is the ellipsoid

$$(A', B', C', F', G', H' \between x, y, z)^2 = Mk^4,$$

where k is arbitrary, so that the absolute magnitude is not determined. But it is more usual, and in some respects better to consider in place thereof the "Momental Ellipsoid" (Cauchy, "Sur les Moments d'Inertie," Exercices de Mathématique, t. ii. pp. 93–103, 1827),

$$(A, B, C, F, G, H \between x, y, z)^2 = Mk^4,$$

or as it may also be written,

$$(A'+B'+C')(x^2+y^2+z^2)-(A', B', C', F', G', H' \between x, y, z)^2 = Mk^4,$$

which shows that the two ellipsoids have their axes, and also their circular sections coincident in direction.

144. And there is besides this a third ellipsoid, the "Ellipsoid of Gyration," which is the reciprocal of the momental ellipsoid in regard to the concentric sphere, radius k. The last-mentioned ellipsoid is given in magnitude, viz., if the body is referred to its principal axes, then putting $A=Ma^2$, $B=Mb^2$, $C=Mc^2$, the equation of the ellipsoid of gyration is

$$\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}=1.$$

The axes of any one of the foregoing ellipsoids coincide in direction with the principal axes of the body, and the magnitudes of the axes lead very simply to the values of the principal moments A, B, C.

145. The origin has so far been left arbitrary: in the dynamical applications, this origin is in the case of a solid body rotating about a fixed point, the fixed point; and in the case of a free body, the centre of gravity. But the values of the coefficients (A, B, C, F, G, H), or (A', B', C', F', G', H'), corresponding to any given origin whatever, are very easily expressed in

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* I have ventured to make this change instead of writing as usual $F=\int yz dm$, &c.; as in most cases $F=G=H=0$, the formulæ affected by the alteration are not numerous.

terms of the coordinates of this origin, and the values of the corresponding coefficients for the centre of gravity as origin; or, what is the same thing, any one of the ellipsoids for the given origin may be geometrically constructed by means of the ellipsoid for the centre of gravity. The geometrical theory, as regards the magnitudes of the axes, does not appear to have been anywhere explicitly enunciated; as regards their direction, it is comprised in the theorem that the directions at any point are the three rectangular directions at that point in regard to the ellipsoid of gyration for the centre of gravity*, *post*, No. 159. The notion of the ellipsoids, and of the relation between the ellipsoids at a given point and those at the centre of gravity, once established, the theory of principal axes and moments of inertia becomes a purely geometrical one.

146. The existence of principal axes was first established by Segner in the work 'Specimen Theoriæ Turbinum,' Halle (1755), where, however, it is remarked that Euler had said something on the subject in the [Berlin] Memoirs for 1749 and 1750 (*post*, No. 167), and had constructed a new mechanical principle, but without pursuing the question. Segner's course of investigation is in principle the same as that now made use of, viz. a principal axis is defined to be an axis, such that when a body revolves round it the forces arising from the rotation have no tendency to alter the position of the axes. It is first shown that there are systems of axes x, y, z such that $\int yz\,dm=0$, and then, in reference to such a set of axes, the position of a principal axis, say the axis of X, is determined by the conditions $\int \mathrm{XY}\,dm=0$, $\int \mathrm{XZ}\,dm=0$, viz. the unknown quantities being taken to be $t=\frac{\cos\alpha}{\cos\gamma}$, $\tau=\frac{\cos\beta}{\cos\gamma}$ (α, β, γ, being the inclinations of the principal axis to those of x, y, z), and then putting $\mathrm{A}=\int x^2dm$, &c. ($\mathrm{F}=0$ by hypothesis), Segner's equations for the determination of t, τ are

$$\begin{gathered}\mathrm{G}'t^2+(\mathrm{C}'-\mathrm{A}')\,t-\mathrm{G}'-\mathrm{H}'\tau=0,\\(\mathrm{C}'-\mathrm{B}')\,\tau-\mathrm{G}'t\tau+\mathrm{H}'t=0,\end{gathered}$$

the second of which gives

$$\tau=\frac{\mathrm{H}'t}{\mathrm{B}'-\mathrm{C}'+\mathrm{G}'t},$$

and by means of it the first gives

$$\mathrm{G}'^2t^3-\mathrm{G}'(\mathrm{A}'-\mathrm{B}')t^2+\{(\mathrm{B}'-\mathrm{C}')(\mathrm{C}'-\mathrm{A}')-\mathrm{G}'^2-\mathrm{H}'^2\}\,t+\mathrm{G}'(\mathrm{B}'-\mathrm{C}')=0,$$

which being a cubic equation shows that there are three principal axes; and it is afterwards proved that these are at right angles to each other.

147. To show the equivalence of Segner's solution to the modern one, I remark that if $u=\int \mathrm{X}^2dm$, we have

$$\begin{array}{llll}(\mathrm{A}'-u)\,t+ & \mathrm{H}' & \tau+\mathrm{G}' & =0,\\ \mathrm{B}' & t+(\mathrm{B}'-u) & \tau+\mathrm{F}' & =0,\\ \mathrm{G}' & t+\quad\mathrm{F}' & \tau+\mathrm{C}'-u & =0,\end{array}$$

whence

---

* The rectangular directions at a point in regard to an ellipsoid are the directions of the axes of the circumscribed cone, or, what is the same thing, they are the directions of the normals to the three quadric surfaces confocal with the given ellipsoid, which pass through the given point. The theory of confocal surfaces appears to have been first given by Chasles, Note XXXI. of the 'Aperçu Historique' (1837).

$$
\begin{aligned}
t^2 : \tau^2 : 1 : \tau : t : t\tau = {} & B'C' - F'^2 - (B'+C')u + u^2, \\
: {} & C'A' - G'^2 - (C'+A')u + u^2, \\
: {} & A'B' - H'^2 - (A'+B')u + u^2, \\
: {} & G'H' - A'F' \qquad + F'u, \\
: {} & H'F' - B'G' \qquad + G'u, \\
: {} & F'G' - C'H' \qquad + H'u,
\end{aligned}
$$

or putting therein $F'=0$,

$$
\begin{aligned}
t^2 : \tau^2 : 1 : \tau : t : t\tau = {} & B'C' \qquad - (B'+C')u + u^2 \\
: {} & C'A' - G'^2 - (C'+A')u + u^2 \\
: {} & A'B' - H'^2 - (A'+B')u + u^2 \\
: {} & G'H' \\
: {} & -B'G' + G'u \\
: {} & -C'H' + H'u
\end{aligned}
$$

by means of which Segner's equations may be verified. I have given this analysis, as the first solution of such a problem is a matter of interest.

148. There is little if anything added to Segner's results by the memoir, Euler, "Recherches sur la Connaissance Mécanique des Corps" (1758), which is introductory to the immediately following one on Rotation.

149. Relating to the theory of principal axes we have Binet's "Mémoire sur les Axes Conjugués," &c. (1813). The author proposes to make known the new systems of axes which he calls *conjugate axes*, which, when they are at right angles to each other, coincide with the principal axes; viz. considering the sum of the molecules each into its distance from a plane, such distance being measured in the direction of a line, then (the direction of the line being given) of all the planes which pass through a given point, there is one for which the sum in question is a minimum, and this plane is said to be *conjugate* to the given line, and from the notion of a line and conjugate plane he passes to that of a system of *conjugate* axes. The investigation (which is throughout an elegant one) is conducted analytically; the coordinates made use of are oblique ones, and the formulæ are thus rendered more complicated than they would otherwise have been; in referring to them it will be convenient to make the axes rectangular.

150. One of the results is the well-known equation

$$(A'-\Theta)(B'-\Theta)(C'-\Theta)-F'^2(A'-\Theta)-G'^2(B'-\Theta)-H'^2(C'-\Theta)+2F'G'H'=0;$$

which, if x_1, y_1, z_1 are the principal axes, has for its roots $\int x_1^2 dm$, $\int y_1^2 dm$, $\int z_1^2 dm$.

And the equations (1), p. 49, taking therein the original axes as rectangular, are

$$
\begin{aligned}
\left(\mathfrak{A}'-\frac{K'}{\Theta'}\right)\cos\alpha + {} & \mathfrak{H}' \cos\beta + \mathfrak{G}' \cos\gamma = 0, \\
+\mathfrak{H}' \cos\alpha + {} & \left(\mathfrak{B}'-\frac{K'}{\Theta'}\right)\cos\beta + \mathfrak{F} \cos\gamma = 0, \\
+\mathfrak{G}' \cos\alpha + {} & \mathfrak{F} \cos\beta + \left(\mathfrak{C}'-\frac{K'}{\Theta'}\right)\cos\gamma = 0,
\end{aligned}
$$

where $\mathfrak{A}'$, $\mathfrak{B}'$, $\mathfrak{C}'$, $\mathfrak{F}$, $\mathfrak{G}'$, $\mathfrak{H}'$ denote the reciprocal coefficients $\mathfrak{A}'=B'C'-F'^2$

&c., and K' is the discriminant $=A'B'C'-A'F'^2-B'G'^2-C'H'^2+2F'G'H'$: this is a symmetrical system of equations for finding $\cos\alpha:\cos\beta:\cos\gamma$, less simple however than the modern form (*post*, No. 154), the identity of which with Binet's may be shown without difficulty.

151. Another result (p. 57) is that if the original axes are principal axes, and if Ox, Oy, Oz are the principal axes through a point the coordinates whereof are f, g, h, and if $\Theta_1'=(\text{say})\int x_1^2dm$, then we have

$$\frac{f^2}{\Theta_1'-A'}+\frac{g^2}{\Theta_1'-B'}+\frac{h^2}{\Theta_1'-C'}=\frac{1}{M}$$

(in which I have restored the mass M, which is put equal to unity), so that if Θ_1' have a given constant value, the locus of the point is a quadric surface, the nature whereof will depend on the value of Θ_1. The surfaces in question are confocal with each other [and with the imaginary surface $\frac{x^2}{-A'}+\frac{y^2}{-B'}+\frac{z^2}{-C'}=\frac{1}{M}$, which is similar to the ellipsoid $\frac{x^2}{A'}+\frac{y^2}{B'}+\frac{z^2}{C'}=\frac{1}{M}$, which is the reciprocal of the comomental ellipsoid $A'x^2+B'y^2+C'z^2=Mk^2$ in regard to a concentric sphere, radius k]. The author mentions the ellipsoid $\frac{x^2}{A'}+\frac{y^2}{B'}+\frac{z^2}{C'}=\frac{1}{M}$ (see p. 64), and he remarks that his conjugate axes are in fact conjugate axes in respect to this ellipsoid, and consequently that the principal axes are in direction the principal axes of this ellipsoid: it is noticeable that the ellipsoid thus incidentally considered is not the comomental ellipsoid itself, but, as just remarked, its reciprocal in regard to a concentric sphere.

152. Poisson, 'Mécanique' (1st ed. 1811, and indeed 2nd ed. 1833), gives the theory of principal axes in a less complete form than in Binet's memoir; for the directions of the principal axes are obtained in anything but an elegant form.

153. Ampère's Memoir (1823).—The expression *permanent axis* is used in the place of principal axis, which is employed to designate a principal axis through the centre of gravity. The memoir contains a variety of very interesting geometrical theorems, which however, as no ellipsoid is made use of, can hardly be considered as exhibited in their proper connexion. The author arrives incidentally at certain conics, which are in fact the focal conics of the ellipsoid of gyration $\left(\frac{x^2}{A}+\frac{y^2}{B}+\frac{z^2}{C}=\frac{1}{M}\right)$ for the centre of gravity.

154. Cauchy, in the memoir "Sur les Momens d'Inertie" (1827), considers the momental ellipsoid $(A, B, C, F, G, H\between x, y, z)^2=1$, and employs it as well to prove the existence of the principal axes as to determine their direction, and also the magnitudes of the principal moments; the results are obtained in the simplest and best forms; viz. the direction cosines are given by

$$\begin{aligned}(A-\Theta)\cos\alpha+H\quad\ \ \cos\beta+G\quad\ \ \cos\gamma&=0,\\ H\quad\ \ \cos\alpha+(B-\Theta)\cos\beta+F\quad\ \ \cos\gamma&=0,\\ G\quad\ \ \cos\alpha+F\quad\ \ \cos\beta+(C-\Theta)\cos\gamma&=0,\end{aligned}$$

where

$$(A-\Theta)(B-\Theta)(C-\Theta)-(A-\Theta)F^2-(B-\Theta)G^2-(C-\Theta)H^2+2FGH=0,$$

Θ being one of the principal moments.

155. Poinsot, "Mémoire sur la Rotation" (1834), defines the "Central

Ellipsoid" as an ellipsoid having for its axes the principal axes through the centre of gravity, the squares of the lengths being reciprocally proportional to the principal moments; and he remarks in passing that *the moment about any diameter of the ellipsoid is inversely proportional to the square of this diameter*. It is to be noticed that Poinsot speaks only of the ellipsoid having its centre at the centre of gravity, but that such ellipsoid may be constructed about any point whatever as centre, so generalized, it is in fact the momental ellipsoid $Ax^2+By^2+Cz^2=Mk^4$; and moreover that Poinsot defines his ellipsoid by reference to the principal axes.

156. Pine, "On the Principal Axes, &c." (1837), obtained analytically in a very elegant manner equations for determining the positions of the principal axes; viz. these are

$$\begin{array}{lll} (A'-\Theta')\cos\alpha+H' & \cos\beta+G' & \cos\gamma=0, \\ H' \qquad \cos\alpha+(B'-\Theta') & \cos\beta+F' & \cos\gamma=0, \\ G' \qquad \cos\alpha+F' & \cos\beta+(C'-\Theta') & \cos\gamma=0, \end{array}$$

where

$$(A'-\Theta')(B'-\Theta')(C'-\Theta')-(A'-\Theta')F'^2-(B'-\Theta')G'^2-(C'-\Theta')F'^2+2F'G'H'=0;$$

viz. these are similar to those of Cauchy, only they belong to the comomental instead of the momental ellipsoid.

157. Maccullagh, in his Lectures of 1844 (see Haughton), considers the momental ellipsoid

$$(A, B, C, F, G, H \between x, y, z)^2=Mk^4$$

(A, B, C, F, G, H *ut suprà*), which is such that the moment of inertia of the body with respect to any axis passing through the origin is proportional to the square of the radius vector of the ellipsoid; and from the geometrical theorem of the ellipsoid having principal axes he obtained the mechanical theorem of the existence of principal axes of the body; at least I infer that he did so, although the conclusion is not explicitly stated in Haughton's account; but in all this he had been anticipated by Cauchy. And afterwards, referring the ellipsoid to its principal axes, so that the equation is $Ax^2+By^2+Cz^2=Mk^4$, he writes $A=Ma^2$, $B=Mb^2$, $C=Mc^2$, which reduces the equation to $a^2x^2+b^2y^2+c^2z^2=k^4$, and he considers the reciprocal ellipsoid $\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}=1$, or, what is the same thing, $\frac{x^2}{A}+\frac{y^2}{B}+\frac{z^2}{C}=\frac{1}{M}$, which is the ellipsoid of gyration.

158. Thomson, "On the Principal Axes of a Solid Body" (1846), shows analytically that the principal axes coincide in direction with the axes of the momental ellipsoid

$$(A, B, C, F, G, H \between x, y, z)^2=Mk^4;$$

but the geometrical theorem might have been assumed: the investigation is really an investigation of the axes of this ellipsoid. And he remarks that the ellipsoid $(A', B', C', F', G', H' \between x, y, z)^2=Mk^4$ (the comomental ellipsoid) might equally well have been used for the purpose.

159. He obtains the before-mentioned theorem that the directions of the principal axes at any point are the rectangular directions in regard to the ellipsoid of gyration $\left(\frac{x^2}{A}+\frac{y^2}{B}+\frac{z^2}{C}=\frac{1}{M}\right)$ for the centre of gravity. And for determining the moments of inertia at the given point (say its coordinates are ξ, η, ζ) he obtains the equation

$$\frac{\xi^2}{\xi^2+\eta^2+\zeta^2+\frac{A-P}{M}}+\frac{\eta^2}{\xi^2+\eta^2+\zeta^2+\frac{B-P}{M}}+\frac{\zeta^2}{\xi^2+\eta^2+\zeta^2+\frac{C-P}{M}}=1,$$

where the three roots of the cubic in P are the required moments. Analytically nothing can be more elegant, but, as already remarked, a geometrical construction for the magnitudes of these moments appears to be required.

160. Some very interesting geometrical results are obtained by considering the "equimomental surface" the locus of the points, for which one of the moments of inertia is equal to a given quantity Π; the equation is of course

$$\frac{x^2}{x^2+y^2+z^2+\frac{A-\Pi}{M}}+\frac{y^2}{x^2+y^2+z^2+\frac{B-\Pi}{M}}+\frac{z^2}{x^2+y^2+z^2+\frac{C-\Pi}{M}}=1,$$

and which includes Fresnel's wave-surface. In particular it is shown that the equimomental surface cuts any surface

$$\frac{x^2}{A+\Theta}+\frac{y^2}{B+\Theta}+\frac{z^2}{C+\Theta}=\frac{1}{M}$$

confocal with the ellipsoid of gyration in a spherical conic and a curve of curvature; a theorem which is also demonstrated, Cayley, "Note on a Geometrical Theorem, &c." (1846).

161. Townsend, "On Principal Axes, &c." (1846).—This elaborate paper is contemporaneous, or nearly so, with Thomson's, and several of the conclusions are common to the two. From the character of the paper, I find it difficult to give an account of it; and I remark that, the theory of principal axes once brought into connexion with that of confocal surfaces, all ulterior developments belong more properly to the latter theory.

162. Haton de la Goupillière's two memoirs, "Sur la Théorie Nouvelle de la Géométrie des Masses" (1858), relate in a great measure to the theory of the integral $\int xydm$, and its variations according to the different positions of the two planes $x=0$ and $y=0$; the geometrical interpretations of the several results appear to be given with much care and completeness, but I have not examined them in detail. The author refers to the researches of Thomson and Townsend.

163. I had intended to show (but the paper has not been completed for publication) how the momental ellipsoid for any point of the body may be obtained from that for the centre of gravity by a construction depending on the "square potency" of a point in regard to the last-mentioned ellipsoid.

The Rotation of a solid body. Article Nos. 164–207.

164. It will be recollected that the problem is the same for a body rotating about a fixed point, and for the rotation of a free body about the centre of gravity; the case considered is that of a body not acted on by any forces. According to the ordinary analytical mode of treatment, the problem depends upon Euler's equations

$$\begin{aligned}Adp+(C-B)\,qrdt&=0,\\ Bdq+(A-C)\,rpdt&=0,\\ Cdr+(B-A)\,pqdt&=0,\end{aligned}$$

for the determination of p, q, r, the angular velocities about the principal axes; considering p, q, r as known, we obtain by merely geometrical considerations a system of three differential equations of the first order for the determination of the position in space of the principal axes.

165. The solution of these, which constitutes the chief difficulty of the problem, is usually effected by referring the body to a set of axes fixed in space, the position whereof is not arbitrary, but depends on the initial circumstances of the motion; viz. the axis of z is taken to be perpendicular to the so-called *invariable plane*. The solution is obtained *without* this assumption both by Euler and Lagrange, although, as remarked by them, the formulæ are greatly simplified by making it; it is, on the other hand, made in the solution (which may be considered as the received one) by Poisson; and the results depending on it are the starting-point of the ulterior analytical developments of Rueb and Jacobi; the method of Poinsot is also based upon the consideration of the invariable plane.

166. D'Alembert's principle, which affords a direct and general method for obtaining the equations of motion in any dynamical problem whatever, was given in his "Traité de Dynamique" (1743); and in his memoir of 1749 he applied it to the physical problem of the Precession of the Equinoxes, which is a special case of the problem of Rotation, the motion of rotation about the centre of gravity being in fact similar to that about a fixed point. But, as might be expected in the first attempt at the analytical treatment of so difficult a problem, the equations of motion are obtained in a cumbrous and unmanageable form.

167. They are obtained by Euler in the memoir "Découverte d'un Nouveau Principe de Mécanique," Berlin Memoirs for 1750 (1752) (written before the establishment of the theory of principal axes), in a perfectly elegant form, including the ordinary one already mentioned, and, in fact, reducible to it by merely putting the quantities F, G, H (which denote the integrals $\int yz\,dm$, &c.) equal to zero. But Euler does not in this memoir enter into the question of the integration of the equations.

168. The notion of principal axes having been suggested by Euler, and their existence demonstrated by Segner, we come to Euler's investigations contained in the memoirs "Du Mouvement de Rotation &c.," Berlin Memoirs for 1758 (printed 1765) and for 1760 (printed 1767), and the "Theoria Motus Corporum Solidorum &c." (1765). In the memoir of 1760, and in the "Theoria Motus," Euler employs ϖ, the angular velocity round the instantaneous axis, but not the resolved velocities $\varpi\cos\alpha$, $\varpi\cos\beta$, $\varpi\cos\gamma$ $(=p, q, r)$: these quantities (there called x, y, z) are however employed in the memoir, Berlin Memoirs (1758), which must, I apprehend, have been written after the other, and in which at any rate the solution is developed with much greater completeness. It is in fact carried further than the ordinary solutions, and after the angular velocities p, q, r have been found, the remaining investigation for the position in space of the principal axes, conducted, as above remarked, without the aid of the invariable plane, is one of great elegance.

169. In the last-mentioned memoir Euler starts from the equations given by d'Alembert's principle; viz. the impressed forces being put equal to zero, these are

$$\Sigma dm\left(y\frac{d^2z}{dt^2}-z\frac{d^2y}{dt^2}\right)=0, \&c.,$$

or, what is the same thing, using u, v, w to denote the velocities of an element in the directions of the axes fixed in space, these are

$$\Sigma dm\left(y\frac{dw}{dt}-z\frac{dv}{dt}\right)=0,$$
$$\Sigma dm\left(z\frac{du}{dt}-x\frac{dw}{dt}\right)=0,$$
$$\Sigma dm\left(x\frac{dv}{dt}-y\frac{dy}{dt}\right)=0.$$

It is assumed that at any moment the body revolves round an instantaneous axis, inclinations α, β, γ, with an angular velocity ȣ; this gives

$$u=\text{ȣ}(z\cos\beta-y\cos\gamma)=qz-ry,$$
$$v=\text{ȣ}(x\cos\gamma-z\cos\alpha)=rx-pz,$$
$$w=\text{ȣ}(y\cos\alpha-x\cos\beta)=px-qy,$$

if $\text{ȣ}\cos\alpha$, $\text{ȣ}\cos\beta$, $\text{ȣ}\cos\gamma$ are denoted by p, q, r. The values of du, dv, dw are obtained by differentiating these formulæ, treating p, q, r, x, y, z as variable, and replacing dx, dy, dz by udt, vdt, wdt respectively; in the resulting formulæ for $ydw-zdv$, &c., x, y, z are considered as denoting the coordinates of the element in regard to axes fixed in the body and moveable with it, but which at the moment under consideration coincide in position with the axes fixed in space. The expressions for $\Sigma(ydw-zdv)\,dm$ involve the integrals $A=\int(y^2+z^2)\,dm$, &c., where the coordinates refer to axes fixed in the body; and if these are taken to be principal axes, the expression for $\Sigma(ydw-zdv)\,dm$ is $=Adp+(C-B)\,qrdt$, which gives the three equations

$$Adp+(C-B)\,qrdt=0,$$
$$Bdq+(A-C)\,rpdt=0,$$
$$Cdr+(B-A)\,pqdt=0,$$

already referred to as Euler's equations.

170. Next, as regards the determination of the position in space of the principal axes: if about the fixed point we describe a sphere meeting the principal axes in x_1, y_1, z_1, and if P be an arbitrary point on the sphere and PQ an arbitrary direction through P, the quantities used to determine the positions of x_1, y_1, z_1 are the distances x_1P, y_1P, z_1P $(=l, m, n)$ and the inclinations x_1PQ, y_1PQ, z_1PQ $(=\lambda, \mu, \nu)$ of these arcs to the fixed direction PQ (it is to be observed that the sines and cosines of the differences of λ, μ, ν are given functions of the sines and cosines of l, m, n, and, moreover, that $\cos^2 l+\cos^2 m+\cos^2 n=1$, so that the number of independent parameters is three). The above is Euler's definition; but if we consider a set of axes fixed in space meeting the sphere in the points X, Y, Z, then if the point X be taken for P, and the arc XY for PQ, it is at once seen that the angles used for determining the relative positions of the two sets of axes are the same as in Euler's memoir "Formulæ Generales, &c.," 1775 (*ante*, No. 132), where the formulæ for this transformation of coordinates are considered apart from the dynamical theory.

Euler expresses the quantities p, q, r in terms of an auxiliary variable u, which is such that $du=pqrdt$; p, q, r are at once obtained in terms of u, and then t is given in terms of u by a quadrature. Euler employs also an auxiliary angle U, given in terms of u by a quadrature. And he obtains finite algebraical expressions in u, cos U, sin U for the cosines or sines of l, m, n; s (the angular distance IP, if I denote the point in which the instantaneous axis meets the sphere), ϕ (the angle IPQ) and $\lambda-\phi$, $\mu-\phi$, $\nu-\phi$.

The formulæ, although complicated, are extremely elegant, and they appear to have been altogether overlooked by subsequent writers.

171. Euler remarks, however, that the complexity of his solution is owing to the circumstance that the fixed point P is left arbitrary, and that they may be simplified by taking this point so as that a certain relation $G-\mathfrak{B}^2=0$ may be satisfied between the constants of the solution; and he gives the far more simple formulæ corresponding to this assumption. This amounts to taking the point P *in the normal of the invariable plane*, and the resulting formulæ are in fact identical with the ordinary formulæ for the solution of the problem. The expression *invariable plane* is not used by Euler, and seems to have been first employed in Lagrange's memoir "Essai sur le Problème de Trois Corps," Prix de l'Acad. de Berlin, t. ix. (1772): the theory in reference to the solar system has been studied by Laplace, Poinsot, and others.

172. Lagrange's solution in the memoir of 1773 is substantially the same with that in the 'Mécanique Analytique.' Only he starts from the integral equations of areas and of *Vis Viva*, but in the last-mentioned work from the equations of motion as expressed in the Lagrangian form by means of the *Vis Viva* function $T\left(=\frac{1}{2}\Sigma(x'^2+y'^2+z'^2)dm\right)$. The distinctive feature is that he does not refer the body to the principal axes but to any rectangular axes whatever fixed in the body: the expression for T consequently is $T=\frac{1}{2}(A, B, C, F, G, H\between p, q, r)^2$, instead of the more simple form

$$T=\tfrac{1}{2}(Ap^2+Bq^2+Cr^2),$$

which it assumes when the body is referred to its principal axes. And Lagrange effects the integration as well with this more general form of T, as without the simplification afforded by the invariable plane; the employment, however, of the more general form of T seems an unnecessary complication of the problem, and the formulæ are not worked out nearly so completely as in Euler's memoir. It may be observed that p, q, r are expressed as functions of the instantaneous velocity $\omega(=\sqrt{p^2+q^2+r^2})$, and thence t obtained by a quadrature as a function of ω.

173. Poisson's Memoir of 1809.—The problem is only treated incidentally for the sake of obtaining the expressions for the variations of the arbitrary constants; the results (depending, as already remarked, on the consideration of the invariable plane) are obtained and exhibited in a very compact form, and they have served as a basis for further developments; it will be proper to refer to them somewhat particularly. The Eulerian equations give, in the first place, the integrals

$$\begin{aligned} Ap^2+Bq^2+Cr^2&=h,\\ A^2p^2+B^2q^2+C^2r^2&=k^2; \end{aligned}$$

and then by means of these, p, q being expressed in terms of r, we have t in terms of r by a quadrature.

174. The position in space of the principal axes is determined by referring them, by means of the angles θ, ϕ, ϖ, to axes Ox, Oy, Oz fixed in space; if, to fix the ideas, we call the plane of xy the ecliptic (Ox being the origin of longitudes), and the plane of the two principal axes $x_1\, y_1$ the equator, then we have

θ, the longitude of node,
ϕ, the inclination,
ϖ, the hour-angle, or angular distance of Ox_1 from the node,

and α, β, γ the cosine inclinations of Ox_1, α', β', γ' those of Oy_1, and $\alpha'', \beta'', \gamma''$

those of Oz_1 to Ox, Oy, Oz respectively are given functions of θ, ϕ, τ (the values of α'', β'', γ'' depending upon θ, ϕ only), we have

$$\begin{aligned} p\,dt&=\sin\tau\sin\phi\, d\theta+\cos\tau\, d\phi,\\ q\,dt&=\cos\tau\sin\phi\, d\theta-\sin\tau\, d\phi,\\ r\,dt&=d\tau+\cos\phi\, d\theta. \end{aligned}$$

175. A set of integrals is

$$\begin{aligned} \mathrm{A}p\alpha\ +\mathrm{B}q\beta\ +\mathrm{C}r\gamma\ &=k\cos\lambda,\\ \mathrm{A}p\alpha'\ +\mathrm{B}q\beta'\ +\mathrm{C}r\gamma'\ &=k\cos\mu,\\ \mathrm{A}p\alpha''+\mathrm{B}q\beta''+\mathrm{C}r\gamma''&=k\cos\nu, \end{aligned}$$

equivalent to two independent equations, the values of λ, μ, ν being such that $\cos^2\lambda+\cos^2\mu+\cos^2\nu=1$; but the position of the axis of z may be chosen so that the values on the right-hand sides become 0, 0, k; the axis of z is then perpendicular to the *invariable plane*, the condition in question serving as a definition. And the three equations then give

$$\mathrm{A}p=k\alpha'',\quad \mathrm{B}q=k\beta'',\quad \mathrm{C}r=k\gamma'',$$

where the values of α'', β'', γ'' in fact are

$$\alpha''=\sin\tau\sin\phi,\quad \beta''=\cos\tau\sin\phi,\quad \gamma''=\cos\phi;$$

we have thus τ, ϕ in terms of r. And the equation $r\,dt=d\tau+\cos\phi\, d\theta$ then leads to the value of $d\theta$, or θ is determined as a function of r by a quadrature.

176. The constants of integration are h, k, l (the constant attached to t), g (the constant attached to θ); and two constants, say α the longitude of the node, and γ the inclination of the invariable plane in reference to an arbitrary plane of xy and origin x of longitudes therein. I remark in passing that Poisson obtains an elegant set of formulæ for the variations of the constants h, k, g, l, α, γ, not actually in the canonical form, but which may by a slight change be reduced to it.

177. Legendre considers the problem of Rotation in the 'Exercices de Calcul Intégral,' t. ii. (1817), and the "Théorie des Fonctions Elliptiques," t. i. pp. 366–410 (1826). He does not employ the quantities p, q, r, but obtains *de novo* a set of differential equations of the second order involving the angles which determine the position of the principal axes with regard to the axes fixed in space: these angles are in fact (calling the plane of the fixed axes x, y the ecliptic) the longitude and latitude of *one* of the principal axes, and the azimuth from the meridian through such principal axis of an arbitrary axis fixed in the body and moveable with it. The solution is developed by means of the elliptic *integrals*. From the peculiar choice of variables there would, it would seem, be considerable labour in comparing the results with those of other writers, and there would be but little use in doing so.

178. Poinsot's "Théorie Nouvelle de la Rotation des Corps."—The 'Extrait' of the memoir was published in 1834, but the memoir itself was not published *in extenso* until the year 1851. The 'Extrait' contains, however, not only the fundamental theorem of the representation of the motion of a body about a fixed point by means of the momental ellipsoid rolling on a fixed tangent plane, but also the geometrical and mechanical reasonings by which this theorem is demonstrated; it establishes also the notions of the Poloid and Serpoloid curves; and it contains incidentally, and without any developments, a very important remark as to the representation of the motion by means of the rolling and sliding motion of an elliptic cone. The whole theory (including that of the last-mentioned representation of the motion) is in the memoir

itself also analytically developed, but without the introduction of the elliptic and Jacobian functions: to form a complete theory, it would be necessary to incorporate the memoir with that of Jacobi.

179. The following is an outline of the 'Extrait':—

The instantaneous motion of a body about a fixed point is a motion of rotation about an axis (the instantaneous axis); and hence the finite motion is as if there were a cone fixed in the body which rolls (without sliding) upon another cone fixed in space.

The instantaneous motion of a body in space is a motion of rotation about an axis combined with a translation in the direction of this axis: this remark is hardly required for Poinsot's purpose, and he does not further develope the theory of the motion of a body in space. The effect of a couple in a plane perpendicular to a principal axis is to turn the body about this axis with an angular velocity proportional to the moment of the couple divided by the moment of inertia about the axis.

And hence by resolving any couple into couples perpendicular to the principal axes, the effect of such couple may be calculated; but more simply by means of the central ellipsoid (momental ellipsoid $a^2x^2+b^2y^2+c^2z^2=k^4$, if $A, B, C=Ma^2, Mb^2, Mc^2$), viz., if the body is acted on by a couple in a tangent plane of the ellipsoid, the instantaneous axis passes through the point of contact; and reciprocally given the instantaneous axis, the couple must act in the tangent plane.

180. Considering now a body rotating about a fixed point, and taking as the plane of the couple of impulsion a tangent plane of the ellipsoid, the instantaneous axis is initially the diameter through the point of contact; the centrifugal forces arising from the rotation produce however an accelerating couple, the effect whereof is continually to impress on the body a rotation which is compounded with that about the instantaneous axis, and thus to cause a variation in the position of this axis and in the angular velocity round it. The axis of the accelerating couple is always situate in the plane of the couple of impulsion.

181. Hence also

1°. Throughout the motion the angular velocity is proportional to the length of the instantaneous axis considered as a radius vector of the ellipsoid.

2°. The distance of the tangent plane from the centre is constant; that is, the tangent plane to the ellipsoid at the extremity of the instantaneous axis is a fixed plane in space.

Or, what is the same thing, the motion is such that the ellipsoid remains always in contact with a fixed plane, viz., the body revolves round the radius vector through the point of contact, the angular velocity being always proportional to the length of this radius vector.

It is right to remark that in Poinsot's theory the distance of this plane from the centre depends on the arbitrarily assumed magnitude of the central ellipsoid; the parallel plane through the centre is the invariable plane of the motion.

182. The motion is best understood by the consideration that it is implied in the theorem that the pole of the instantaneous axis describes on the ellipsoid a certain curve, "the Poloid," which is the locus of all the points for which the perpendicular on the tangent plane has a given constant value (the curve in question is easily seen to be the intersection of the ellipsoid by a concentric cone of the second order); and that the instantaneous axis describes on the fixed tangent plane a curve called the Serpoloid, which is the locus of the points with which the several points of the poloid come successively in con-

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tact with the tangent plane, and is a species of undulating curve, viz., the radius vector as it moves through the angles θ to $\theta_1+2\Pi$, $\theta_1+2\Pi$ to $\theta_1+4\Pi$, &c. assumes continually the same series of values. This is in fact evident from the mode of generation; and it is moreover clear that the serpoloid is an algebraical or else a transcendental curve according as Π is or is not commensurable with π.

[Treating the poloid and serpoloid as cones instead of curves, the motion of the body is the rolling motion of the former upon the latter cone, which agrees with a previous remark.]

There is a very interesting special case where the perpendicular distance from the tangent plane is equal to the mean axis of the ellipse.

183. Poinsot remarks that the motion is such that [considering the plane of the couple of impulsion as drawn through the centre of the ellipsoid] the section of the ellipsoid is an ellipse variable in form but of constant magnitude, and that this leads to a new representation of the motion, viz., that it may be regarded as the *motion of an elliptic cone which rolls on the plane of the couple* [the invariable plane] *with a variable velocity, and which slides on this plane with a uniform velocity.*

184. The theory of the last-mentioned cone, say the "rolling and sliding cone," is developed in the memoir, Liouville, t. xvi. p. 303, in the chapter entitled "Nouvelle Image de la Rotation des Corps." If a, b, c signify as before (viz., A, B, $\mathrm{C}=\mathrm{M}a^2$, $\mathrm{M}b^2$, $\mathrm{M}c^2$), and if h be the distance of the centre from Poinsot's fixed tangent plane ($h<a>c$), then the invariable axis describes in the body a cone the equation whereof is

$$(a^2-h^2)\,x^2+(b^2-h^2)\,y^2+(c^2-h^2)\,z^2=0\,;$$

the cone reciprocal to this, viz. the cone the equation whereof is

$$\frac{x^2}{a^2-h^2}+\frac{y^2}{b^2-h^2}+\frac{z^2}{c^2-h^2}=0,$$

is the "rolling and sliding cone." The generating line OT of this cone is perpendicular to the plane of the instantaneous axis OI, and of the invariable axis OG; and the analytical expressions for the rolling and sliding velocities follow from the geometrical consideration that the motion at any instant is a rotation round the instantaneous axis OI: that for the sliding velocity is the instantaneous angular velocity into the cosine of the angle IOG, which is in fact constant; that for the rolling velocity is given, but a further explanation of the geometrical signification is perhaps desirable.

185. I may in this place again refer to Cohen's memoir "On the Differential Coefficients and Determinants of Lines &c." (1862), the latter part of which contains an application of the method to finding Euler's equations for the motion of a rotating body.

186. Rueb in his memoir (1834) first applied the elliptic and Jacobian functions to the present problem. Starting from the equations

$$\mathrm{A}p^2+\mathrm{B}q^2+\mathrm{C}r^2=h,$$
$$\mathrm{A}^2p^2+\mathrm{B}^2q^2+\mathrm{C}^2r^2=l^2\text{*},$$

and

$$dt=\frac{-\mathrm{B}\,dq}{(\mathrm{A}-\mathrm{C})\,rp},$$

it is easy to perceive that by assuming $q=$ a proper multiple of $\sin\xi$, the expression for dt takes the form $ndt=\frac{d\xi}{\sqrt{1-k^2\sin^2\xi}}$, so that writing $\xi=\operatorname{am} u$, the integral equation is $nt-\epsilon=u$, or u is an angle varying directly as the time (and corresponding to the mean longitude, or, if we please, to the mean anomaly in the problem of elliptic motion). And then p, q, r are expressed as elliptic functions of u. The value of the modulus k, and that of n ($nt-\epsilon=u$ *ut suprà*) are

---

* l is Poisson's k, the constant of the principal area; it is the letter afterwards used by Jacobi; Rueb's letter is g. In quoting (*infrà*) the expressions for p, q, r, I have given them with Rueb's signs, but it would be too long to explain how the signs of the radicals are determined.

$$n=\sqrt{\frac{(B-C)(-l^2+Ah)}{ABC}},$$

$$k=\sqrt{\frac{(A-B)(l^2-Ch)}{ABC}},$$

and then

$$\left.\begin{aligned} p&=\pm\sqrt{\frac{l^2-Ch}{A\,.\,A-C}}\cos\operatorname{am}u,\\ q&=-\sqrt{\frac{l^2-Ch}{B\,.\,B-C}}\sin\operatorname{am}u,\\ r&=\sqrt{\frac{-l^2+Ah}{C\,.\,A-C}}\Delta\operatorname{am}u.\end{aligned}\right\}$$

187. Substituting for p, q, r their values in terms of u, we have $d\theta$, and thence θ (the longitude of the node of the equator on the invariable plane) in the form

$$\theta=-\frac{l}{An}u+i\Pi(u,ia)\quad(i=\sqrt{-1}),$$

which by Jacobi's formulæ for the transformation of the elliptic integral of the third class becomes

$$\theta=\left(-\frac{l}{An}+iZ(ai)\right)u+\tfrac{1}{2}i\log\frac{\Theta(u-ai)}{\Theta(u+ai)},$$

which Rueb reduces to the real form

$$\theta=-n'u+\tan^{-1}W,$$

W being given in the form of a fraction, the numerator and denominator whereof are series in multiple sines and multiple cosines respectively of $\frac{\pi u}{2K}$.

188. Rueb investigates also the values in terms of u of the cosine inclinations of the instantaneous axis to the axes fixed in space; and he obtains a very elegant expression for the angle ζ, which is the angular distance from x of the projection on the plane of xy (the invariable plane) of the instantaneous axis; viz., this is

$$\zeta=\tan^{-1}\left(-\frac{ABn}{(A-B)l}\,\frac{\Delta\operatorname{am}u}{\sin\operatorname{am}u\cos\operatorname{am}u}\right)-\theta,$$

and there is throughout a careful discussion of the geometrical signification of the results.

189. The advance made was enormous; the result is that we have in terms of the time $\sin\tau\sin\phi$, $\cos\tau\sin\phi$, $\cos\phi$ (the cosine inclinations of the invariable axis to the principal axes), and also θ, the longitude of the node. The cosine inclinations of the axes of x and y to the principal axes could of course be obtained from these, but they would be of a very complicated and un-

manageable form; *the reason of this is the presence in the expression for θ of the non-periodic term $-n'u$.* It will presently be seen how this difficulty was got over by Jacobi.

190. Briot's paper of 1842 contains an analytical demonstration of some of the theorems given in the 'Extrait' of Poinsot's memoir of 1834.

191. In Maccullagh's Lectures of 1844 (see Haughton, 1849; Maccullagh, 1847) the problem of the rotation of a solid body is treated in a mode somewhat similar to that of Poinsot's; only the ellipsoid of gyration $\left(\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}=1,\right.$ if $\mathrm{A}, \mathrm{B}, \mathrm{C}=\mathrm{M}a^2, \mathrm{M}b^2, \mathrm{M}c^2$) is used instead of *the momental ellipsoid.* Thus, reciprocal to the poloid curve on the momental ellipsoid we have on the ellipsoid of gyration a curve all the points whereof are equidistant from the centre; such curve is of course the intersection of the ellipsoid by a concentric sphere, that is, it is a spherical conic; and the points of this spherical conic come successively to coincide with a fixed point on the invariable axis. This is a theorem stated in Art. VI. of Haughton's memoir: it may be added that the several tangent planes of the ellipsoid of gyration at the points of the spherical conic as they come to coincide with the fixed point, form a cone reciprocal to Poinsot's serpoloid cone. It is clear that every theorem in the one theory has its reciprocal in the other theory; I have not particularly examined as to how far the reciprocal theorems have been stated in the two theories.

192. Cayley, "On the Motion of Rotation of a Solid Body" (1843).—The object was to apply to the solution of the problem Rodrigues' formulæ for the resultant rotation; viz., if the principal axes, considered as originally coinciding with the axes of x, y, z, can be brought into their actual position at the end of the time t by a rotation θ round an axis, inclined at angles f, g, h to the axes of x, y, z, and if $\lambda=\tan\frac{1}{2}\theta\cos f$, $\mu=\tan\frac{1}{2}\theta\cos g$, $\nu=\tan\frac{1}{2}\theta\cos h$, then the principal axes are referred to the axes fixed in space by means of the quantities λ, μ, ν. And these are to be obtained from the equations

$$\begin{aligned}\kappa p dt&=2(\quad d\lambda+\nu d\mu-\mu d\nu),\\ \kappa q dt&=2(-\nu d\lambda+\quad d\mu+\lambda d\nu),\\ \kappa r dt&=2(\quad \mu d\lambda-\lambda d\mu+\quad d\nu),\end{aligned}$$

where $\kappa=1+\lambda^2+\mu^2+\nu^2$, and p, q, r are to be considered as given functions of t, or of other the variable selected as the independent one. But for effecting the integration it was found necessary to take the axes of z as the invariable axes.

193. The solution by Jacobi, § 27 of the memoir "Theoria Novi Multiplicatoris" (1845), is given as an application of the general theory, the author remarking that, as well in this question as in the problem of the two fixed centres, he purposely employed a somewhat inartificial analysis, in order to show that the principle (of the Ultimate Multiplier) would lead to the result without any special artifices. The principal axes are referred to the axes fixed in space by the ordinary three angles (here called q_1, q_2, q_3), and the solution is carried so far as to give the integral equations, without any reduction of the integrals contained in them to elliptic integrals. The solution is, however, in so far remarkable that the integrations are effected without the aid of the invariable plane.

194. Cayley, "On the Rotation of a Solid Body &c." (1846).—It appeared desirable to obtain the solution by means of the quantities λ, μ, ν, *without the assistance of the invariable plane,* and Jacobi's discovery of the theorem of the

Ultimate Multiplier induced me to resume the problem, and at least attempt to bring it so far as to obtain a differential equation of the first order between two variables only, the multiplier of which could be obtained theoretically by Jacobi's discovery. The choice of two new variables to which the equations of the problem led me, enabled me to effect this in a simple manner; and the differential equation which I finally obtained turned out to be integrable *per se*, so that the laborious process of finding the multiplier became unnecessary.

195. The new variables Ω, υ have the following geometrical significations: $\Omega = l \tan \frac{1}{2}\theta \cos \mathrm{I}$, where l is the principal moment $(\mathrm{A}^2p^2+\mathrm{B}^2q^2+\mathrm{C}^2r^2=l^2)$, θ (as before) the angle of resultant rotation, and I is the inclination of the resultant axis to the invariable axis; and $\upsilon = l^2 \cos^2 \frac{1}{2}\mathrm{J}$, where if we imagine a line AQ having the same position relatively to the axes fixed in space that the invariable axis has to the principal axes of the body, then J is the inclination of this line to the invariable axis. It is found that p, q, r are functions of υ only, whereas λ, μ, ν contain besides the variable Ω. In obtaining these relations, there occurs a singular relation $\Omega^2 = \kappa\upsilon - l^2$, which may also be written $1+\tan^2 \frac{1}{2}\theta \cos^2 \mathrm{I} = \sec^2 \frac{1}{2}\theta \cos^2 \frac{1}{2}\mathrm{J}$, where the geometrical significations of the quantities I, J have just been explained. The final results are that the time t, and the arc $\tan^{-1}\frac{\Omega}{l}$ are each of them expressible as the integrals of certain algebraical functions of υ. There might be some interest in comparing the results with those of Euler's memoir of 1758, where the principal axes are also referred to an arbitrary system of axes fixed in space; but I was not then acquainted with Euler's memoir.

The concluding part of the paper relates to the determination of the variations of the constants in the disturbed problem.

196. Cayley, "Note on the Rotation of a Solid of Revolution" (1849), shows the simplification produced in the formulæ of the last-mentioned memoir in the case where two of the moments of inertia are equal, say $\mathrm{A}=\mathrm{B}$.

197. Jacobi's final solution of the problem of Rotation was given without demonstration in the letter to the Academy of Sciences at Paris; the demonstration is added in the memoir, Crelle, t. xxxix. (1849). The fundamental idea consists in taking in the invariable plane, instead of the fixed axes xy, a set of axes xy revolving with uniform velocity, such that the angular distance of the axis of x from its initial position is precisely $=-n'u$; and consequently if θ' be the longitude of the node of the equator on the invariable plane, measured from the moveable axis of x as the origin of longitude, we have

$$\theta' = \theta + n'u = \frac{1}{2i} \log \frac{\Theta(u+ia)}{\Theta(u-ia)} \left(i=\sqrt{-1}\right);$$

and in consequence of this form of the expression for θ' $(=\frac{1}{2i}$ into a logarithmic function) in passing to the trigonometrical functions $\sin\theta'$, $\cos\theta'$ the logarithm disappears altogether; and we have in a simple form the expressions for the actual functions $\sin\theta'$, $\cos\theta'$, through which θ' enters into the formulæ, and thus, Jacobi remarks, the barrier is cleared which stands in the way when the expression of an angle is reduced to an elliptic integral of the third class.

198. For the better expression of the results, Jacobi joins to the functions H, Θ, considered in the "Fundamenta Nova," the functions $\Theta_1 u = \Theta(\mathrm{K}-u)$, $\mathrm{H}_1(u) = \mathrm{H}(\mathrm{K}-u)$; so that

$$\sqrt{k}\sin\operatorname{am}u=\frac{\mathrm{H}u}{\Theta u},\quad \sqrt{\frac{k}{k'}}\cos\operatorname{am}u=\frac{\mathrm{H}_1u}{\Theta u},\quad \frac{1}{\sqrt{k'}}\,\Delta\operatorname{am}u=\frac{\Theta_1u}{\Theta u},$$

and then considering the cosine inclinations of the principal axes to the invariable axis and the revolving axes in the invariable plane, these are all fractions which, neglecting constant factors, have the common denominator Θu; α'', β'', γ'' (as shown by Rueb's formulæ) have the numerators H_1u, $\mathrm{H}u$, and Θ_1u respectively; and α, α' have the numerators $\mathrm{H}(u+ia)\pm\mathrm{H}(u-ia)$, β, β' the numerators $\mathrm{H}_1(u-ia)\pm\mathrm{H}_1(u+ia)$, γ, γ' the numerators $\Theta(u+ia)\pm\Theta(u-ia)$ respectively: there are also expressions of a similar form for the angular velocities about the axes of x and y; that about the axis of z (the invariable axis) having, as was known, the constant value $\frac{h}{l}$. The memoir is also very valuable analytically, as completing the systems of formulæ given in the "Fundamenta Nova" in reference to elliptic integrals of the third class.

199. It is worth noticing how the results connect themselves with Poinsot's theorem of the rolling and sliding cone, the velocity of the rolling motion depends only upon the position, on the cone, of the line of contact, so that the same series of velocities recur after any number of complete revolutions of the cone; that is, the total angle described by the line of contact in consequence of the rolling motion, consists of a part varying directly with the time (or say varying as u) and a periodic part; the former part combines with the similar term arising from the sliding motion, and the two together give Jacobi's term $n'u$.

200. Somoff's memoir (1851), written after Jacobi's Note in the 'Comptes Rendus,' but before the appearance of the memoir in Crelle, gives the demonstration of the greater part of Jacobi's results.

201. Booth's "Theory of Elliptic Integrals &c." (1851) (contemporaneous with the publication of Poinsot's memoir of 1834) contains various interesting analytical developments, and, as an interpretation of them, the author obtains (p. 93) the theorem of the rolling and sliding cone. The investigations involve the elliptic integrals, but not the elliptic or Jacobian functions.

202. Richelot's two Notes (Crelle, tt. xlii. & xliv.) relate to the solution of the problem of rotation given in his memoir "Eine neue Losung &c." (1851). This is an application of Jacobi's theorem for the integration of a system of dynamical equations by means of the principal function S (see my "Report" of 1857, art. 34). Retaining Richelot's letters ϕ, ψ, θ, which signify

ψ, the longitude of the node,
θ, the inclination,
ϕ, the hour-angle,

the question is to find a complete solution of the partial differential equation

$$\begin{aligned}0=&\frac{1}{2\mathrm{A}}\left\{\left(\frac{d\mathrm{V}}{d\phi}\cos\theta+\frac{d\mathrm{V}}{d\psi}\right)^2\frac{\sin\phi}{\sin\theta}-\frac{d\mathrm{V}}{d\theta}\cos\varphi\right\}^2\\&+\frac{1}{2\mathrm{B}}\left\{\left(\frac{d\mathrm{V}}{d\phi}\cos\theta+\frac{d\mathrm{V}}{d\psi}\right)\frac{\cos\phi}{\sin\theta}+\frac{d\mathrm{V}}{d\theta}\sin\phi\right\}^2\\&+\frac{1}{2\mathrm{C}}\left(\frac{d\mathrm{V}}{d\phi}\right)^2\quad+\frac{d\mathrm{V}}{dt};\end{aligned}$$

that is, a solution involving (besides the constant attached to V by a mere addition) three arbitrary constants; these are t_1, ψ_1, ρ. Writing in the first place $V = W + tt_1 + \psi\psi_1$, the resulting equation for W may be satisfied by taking W, a function of ϕ and θ, without ψ or t; and it is sufficient to have a solution involving only a single arbitrary constant. This leads to a solution which is as follows,—

$$V = tt_1 + \psi\psi_1 - \psi_1 \tan^{-1} \frac{\theta_1}{\sqrt{\rho^2 - \psi_1^2 - \theta_1^2}}$$

$$+\rho\left\{\tan^{-1}\frac{\psi_1\theta_1}{\rho\sqrt{\rho^2-\psi_1^2-\theta_1^2}} + \tan^{-1}\frac{\phi_1\theta_1}{\rho\sqrt{\rho^2-\phi_1^2-\theta_1^2}}\right\}$$

$$-\left(\frac{\rho^2}{C}+2t_1\right)\int\frac{\phi_1^2 d\phi_1}{(\rho^2-\phi_1^2)\sqrt{\left(\frac{1}{B}-\frac{1}{C}\right)\left(\phi_1^2-\frac{\rho^2}{B}+\quad{}_1\right)\left(\left(\frac{1}{C}-\frac{1}{A}\right)\phi_1^2+\frac{\rho^2}{A}+2t_1\right)}},$$

where ϕ_1 and θ_1 are certain given functions of t_1, ψ_1, ρ, and of θ and ϕ. The solution of the dynamical problem is then obtained by putting the differential coefficients $\frac{dV}{dt_1}$, $\frac{dV}{d\psi_1}$, $\frac{dV}{d\rho}$ equal to arbitrary constants L, α, G respectively; the results are somewhat more simple than might be expected from the very complicated form of the function V. The foregoing results (although not by themselves very intelligible) will give an idea of the form in which the analytical solution in the first instance presents itself.

203. Richelot proceeds to remark that the solution in question, and the resulting integral equations of the problem, may be simplified in a peculiar manner by the method which he calls "the integration by the spherical triangle." For this purpose he introduces a spherical triangle, the sides and angles whereof are

$$\nu, \lambda, \mu; \ N, \Lambda, M,$$

and then assuming

$$N \text{ constant}, \ M = \pi - \theta$$

$$\left(\frac{1}{C}-\frac{1}{A}\right)\sin^2\left(\phi+\nu\right)\sin^2\Lambda + \left(\frac{1}{C}-\frac{1}{B}\right)\cos^2(\phi+\nu)\sin^2\Lambda = \frac{1}{C}+\frac{2t_1}{\rho^2},$$

where ρ and t_1 are constant, the solution is

$$V = t_1 t - \rho(\psi - \lambda)\cos N - \rho M + \rho\int\cos\Lambda d(\phi+\nu);$$

and that this expression leads to all the results almost without calculation.

204. I have quoted the foregoing results from the Note (Crelle, t. xlii.), having seen, but without having studied, the Memoir itself: the results appear very interesting and valuable ones; but they seem to require a more complete geometrical development than they have received in the Memoir; and I am not able to bring them into connexion with the other researches on the subject.

205. The solution, § 3 of Donkin's memoir "On a Class of Differential Equations &c." (part i. 1854), is given as an illustration of the general theory to which the memoir relates; it contains, however, some interesting geometrical developments in regard to the case (A=B) of two equal moments of inertia. I have not compared the results with those in my Note of 1849.

206. The solution of the rotation problem, § 66 of Jacobi's memoir "Nova Methodus &c." (1862), has for its object to show the complete analogy which exists between this problem and the problem of a body attracted to a

fixed centre. The section is in fact headed "Solutio simultanea problematis de motu puncti versus centrum attracti atque problematis de rotatione &c."; and Jacobi, after noticing that Poisson, in his memoir of 1816 (Mém. de l'Inst. t. i.), had shown that the expressions for the variations of the elements in the two problems could be investigated by a common analysis, remarks, "Sed ipsa problemata duo imperturbata hic primum, quantum credo, amplexus sum." The solution is in fact as follows:—Suppose that in the one problem the position of the point in space, and in the other problem the position of the body in regard to the fixed axes is determined in any manner by the quantities q_1, q_2, q_3. Let

$$\frac{dq_1}{dt}=q_1', \frac{dq_2}{dt}=q_2', \frac{dq_3}{dt}=q_3',$$

and expressing the *Vis Viva* function T in terms of $q_1, q_2, q_3, q_1', q_2', q_3$, let

$$\frac{d\mathrm{T}}{dq_1'}=p_1, \frac{d\mathrm{T}}{dq_2'}=p_2, \frac{d\mathrm{T}}{dq_3'}=p_3,$$

and let H be the value of T expressed in terms of $q_1, q_2, q_3, p_1, p_2, p_3$, so that $\mathrm{H}=a$ is the integral of *Vis Viva* (this is merely the transformation to the Hamiltonian form). And let $\mathrm{H}_1=a_1$, $\phi=a_1'$, $\psi=a_1''$ be the three integrals of areas (H, H_1, ϕ, ψ are functions of the variables only, not containing the arbitrary constants a, a_1, a_1', a_1''). Then, expressing

$$\mathrm{H}, \mathrm{H}_1, \mathrm{H}_2 \left(=\sqrt{\mathrm{H}_1^2+\phi^2+\psi^2}\right)$$

in terms of $p_1, p_2, p_3, q_1, q_2, q_3$, and by means of the equations

$$\mathrm{H}=a, \mathrm{H}_1=a_1, \mathrm{H}_2=a_2$$

(where $a_2=\sqrt{a_1^2+a_1'^2+a_1''^2}$) expressing p_1, p_2, p_3 in terms of q_1, q_2, q_3, we have $p_1dq_1+p_2dq_2+p_3dq_3$ a complete differential; and putting

$$\int\left(p_1dq_1+p_2dq_2+p_3dq_3\right)=\mathrm{V},$$

then (a, a_1, a_2, b, b_1, b_2 being arbitrary constants) we have

$$\mathrm{H}=a, \mathrm{H}_1=a_1, \mathrm{H}_2=a_2,$$

$$\frac{d\mathrm{V}}{da}=\int\left(\frac{dp_1}{da}\,dq_1+\frac{dp_2}{da}\,dq_2+\frac{dp_3}{da}\,dq_3\right)=t+b,$$

$$\frac{d\mathrm{V}}{da_1}=\int\left(\frac{dp_1}{da_1}\,dq_1+\frac{dp_2}{dq_1}\,dq_2+\frac{dp_3}{da_1}\,dq_3\right)=b_1,$$

$$\frac{d\mathrm{V}}{da_2}=\int\left(\frac{dp_1}{da_2}\,dq_1+\frac{dp_2}{da_2}\,dq_2+\frac{dp_3}{da_2}\,dq_3\right)=b_2,$$

as the complete integrals of either problem, the last three of them being the final integrals.

And it is added that if in either problem we have $\mathrm{H}+\Omega$ instead of H, the expressions for the variations of the elements assume the canonical forms $\frac{da}{dt}=-\frac{d\Omega}{db}, \frac{db}{dt}=\frac{d\Omega}{da}$, &c.

The solution is not further developed as regards the rotation problem, but it is so (§ 67) as regards the other problem.

207. It must, I think, be considered that a comprehensive memoir on the

Problem of Rotation, embracing and incorporating all that has been done on the subject, is greatly needed.

Kinematics of a solid body. Article Nos. 208 to 215.

208. The general theorem in regard to the infinitesimal motions (rotations and translations) of a solid body is that these are compounded and resolved in the same way as if they were single forces and couples respectively. Thus any infinitesimal rotations and translations are resolvible into a rotation and a translation; the rotation is given as to its magnitude and as to the direction of its axis, but not as to the position of the axis (which may be any line in the given direction): the magnitude and direction of the translation depend on the assumed position of the axis of rotation; in particular this may be taken so that the translation shall be in the direction of the axis of rotation; and the magnitude of the rotation is then a minimum. I remark that the theorem as above stated presupposes the establishment of the theory of couples (of forces) which was first accomplished by Poinsot in his 'Élémens de Statique,' 1st edit. 1804; it must have been, the whole or nearly the whole of it, familiar to Chasles at the date of his paper of 1830 next referred to (see also Note XXXIV of the Aperçu Historique, 1837); and it is nearly the whole of it stated in the 'Extrait' of Poinsot's memoir on Rotation, 1834.

209. Chasles' paper in the 'Bulletin Univ. des Sciences' for 1830.—The corresponding theorem is here given for the finite motions (rotations and translations) of a solid body as follows, viz. if any finite displacement be given to a free solid body in space, there exists always in the body a certain indefinite line which after the displacement remains in its original situation. The theorem is deduced from a more general one relating to two similar bodies. It may be otherwise stated thus: viz., any motions may be represented by a translation and a rotation (the order of the two being indifferent); the rotation is given as regards its magnitude and the direction of its axis, but not as to the position of the axis (which may be any line in the given direction); the magnitude and direction of the translation depend on the assumed position of the axis of rotation; in particular this may be taken so that the translation shall be in the direction of the axis of rotation; the magnitude of the translation is then a minimum.

It may be noticed that a translation may be represented as a couple of rotations; that is, two equal and opposite rotations about parallel axes.

210. It is part of the general theorem that any number of rotations about axes passing through one and the same point may be compounded into a single rotation about an axis through that point; this is, in fact, the theory of the "Resultant Axis" developed in Euler's and Lexell's memoirs of 1775.

211. The following properties are also given, viz., considering two similar solid bodies (or in particular any two positions of a solid body) and joining the corresponding points, the lines which pass through one and the same point form a cone of the second order; and the points of either body form on this cone a curve of the third order (skew cubic). And, reciprocally, the lines, intersections of corresponding planes, which lie in one and the same plane envelope a conic, and such planes of either body envelope a developable surface, which is such that any one of these planes meets it in a conic [or, what is the same thing, the planes envelope a developable surface of the fourth order].

And also, given in space two equal bodies situate in any manner in respect to each other, then joining the points of the first body to the homologous points of the second body, the middle points of these lines form a body capable of an infinitesimal motion, each point of it along the line on which the same is situate.

212. The entire theory, as well of the infinitesimal as of the finite motions of a solid body, is carefully and successfully treated in Rodrigues' memoir "Des lois géométriques &c." (1840). It may be remarked that for the purpose of compounding together any rotations and translations, each rotation may be resolved into a rotation about a parallel axis and a couple of rotations, that is, a translation; the rotations are thus converted into rotations about axes through one and the same point, and these give rise to a single resultant rotation given as to its magnitude and the direction of the axis, but not as to the position of the axis (which is an arbitrary line in the given direction); the translations are then compounded together into a single translation, and finally the position of the axis of rotation is so determined that the translation shall be in the direction of this axis; the entire system is thus compounded (in accordance with Chasles' theorem) into a rotation and a translation in the direction of the axis of the rotation. The problem of the composition depends therefore on the composition of rotations about axes through one and the same point; that is, upon Euler's and Lexell's theory of the resultant axis. But, as already noticed, the analytical theory of the resultant axis was perfected by Rodrigues in the present memoir (see *ante*, 'Transformation of Coordinates,' Nos. 139–141, as to this memoir and the quaternion representation of the formulæ contained in it).

213. It was remarked in Poinsot's memoir of 1834 that every continuous motion of a solid body about a fixed point is the motion of a cone fixed in the body rolling upon another cone fixed in space. The corresponding theorem for the motion of a solid body in space is given

Cayley, "On the Geometrical Representation &c." (1846), viz. premising that a skew surface is said to be "deformed" if, considering the elements between consecutive generating lines as rigid, these elements be made in any manner to turn round and slide along the successive generating lines:—and that two skew surfaces can be made to roll and slide one upon the other, only if the one is a deformation of the other—and that then the rolling and sliding motions are perfectly determined—and that such a motion may be said to be a "gliding" motion: the theorem is that any motion whatever of a solid body in space may be represented as the gliding motion of one skew surface upon another skew surface of which it is the deformation.

214. The same paper contains the enunciation and analytical proof of the following theorem supplementary to that of Poinsot just referred to, viz. that when the motion of a solid body round a fixed point is represented as the rolling motion of one cone on another, then "the angular velocity round the line of contact (the instantaneous axis) is to the angular velocity of this line as the difference of the curvatures of the two cones at any point in this line is to the reciprocal of the distance of the point from the vertex."

215. There are a great number of theorems relating to the composition of forces and force-couples, which consequently relate also to infinitesimal rotations and translations. See, for instance, Chasles, "Théorèmes généraux &c." (1847), Möbius, "Lehrbuch der Statik" (1837), Steichen's Memoirs of 1853 and 1854, &c. Arising out of some theorems of Möbius in the "Statik," we have Sylvester's theory of the involution of six lines: viz. six lines (given in position) may be such that properly selected forces along them (or if we please, properly selected infinitesimal rotations round them) will counterbalance each other; or, what is the same thing, the six lines may be such that a system of forces, although satisfying for each of the six lines the con-

dition moment$=0$, will not of necessity be in equilibrium; such six lines are said to be in involution, and the geometrical theory is a very extensive and interesting one.

Miscellaneous Problems. Article Nos. 216 to 223.

216. As under the foregoing head, "Rotation round a fixed point," I have considered only the case of a body not acted upon by any forces, the case where the body is acted upon by any forces comes under the present head. The forces, whatever they are, may be considered as disturbing forces, and the problem be treated by the method of the variation of the elements; this is at any rate a *separate* part of the theory of rotation round a fixed point, and I have found it convenient to include it under the present head; the only case in which the forces have been treated as principal ones, seems to be that of a heavy body (a solid of revolution) rotating about a point not its centre of gravity. The case of a body suspended by a thread or resting on a plane comes under the present head, as also would (in some at least of the questions connected with it) the gyroscope. But none of these questions are here considered in any detail.

Rotation round a fixed point—Variation of the elements.

217. The forces acting on the body are treated as disturbing forces. Formulæ for the variations of the elements were first obtained by Poisson in the memoir "Sur la Variation des Constantes Arbitraires &c." (1809). The variations are expressed in terms of the differential coefficients of the disturbing function in regard to the *elements*, and, as the author remarks, they are very similar in their form to, and can be rendered identical with, those for the variations of the elements in the theory of elliptic motion.

218. Cayley, "On the Rotation &c." (1846).—The latter part of the paper relates to the variations of the elements therein made use of, which are different from the ordinary ones.

219. Richelot, "Eine neue Lösung &c." (1851).—The form in which the integrals are obtained by means of a function V, satisfying a partial differential equation, leads at once to a canonical system for the variations of the elements; these formulæ are referred to in the introduction to the memoir, but they are not afterwards considered.

220. Cayley, "On the Rotation of a Solid Body" (1860).—The elements are those ordinarily made use of, with only a slight variation occasioned by the employment of the "departure" of the node. The course of the investigation consists in obtaining the variations in terms of the differential coefficients of the disturbing function in regard to *the coordinates* (formulæ which were thought interesting for their own sake), and in deducing therefrom those in terms of the differential coefficients in terms of the *elements*.

Other cases of the motion of a solid body.

221. In regard to a heavy solid of revolution rotating about a fixed point not its centre of gravity, we have

Poisson, "Mémoire sur un cas particulier &c." (1831), and the elaborate memoir

Lottner, "Reduction der Bewegung &c." (1855), where the solution is worked out by means of the Elliptic and Jacobian functions.

222. As regards a heavy solid suspended by a string,

Pagani, "Mémoire sur l'équilibre &c." (1839).

223. As regards the motion of a body resting on a fixed plane,

Cournot, "Mémoire sur le Mouvement &c." (1830 and 1832).
Puiseux, "Du Mouvement &c." (1848).
To which several others might doubtless be added; but the problems are so difficult, that the solutions cannot, it is probable, be obtained in any very complete form.

In conclusion, I can only regret that, notwithstanding the time which has elapsed since the present Report was undertaken, it is still—both as regards the omission of memoirs and works which should have been noticed, and the merely cursory examination of some of those which are mentioned—far from being as complete as I should have wished to make it. To have reproduced, to any much greater extent than has been done, the various mathematical investigations, would not have been proper, nor indeed practicable; at the same time, more especially as regards the subjects treated of in the second part of this Report, or say the kinematics and dynamics of a solid body, such a reproduction, incorporating and to some extent harmonizing the original researches, but without ignoring the points of view and methods of investigation of the several authors, would be a work which would well repay the labour of its accomplishment.

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Report on Double Refraction. By G. G. Stokes, *M.A., D.C.L., Sec.R.S., Lucasian Professor of Mathematics in the University of Cambridge.*

I regret to say that in consequence of other occupations the materials for a complete report on Physical Optics, which the British Association have requested me to prepare, are not yet collected and digested. Meanwhile, instead of requesting longer time for preparation, I have thought it would be well to take up a single branch of the subject, and offer a report on that alone. I have accordingly taken the subject of double refraction, having mainly in view a consideration of the various dynamical theories which have been advanced to account for the phenomenon on the principle of transversal vibrations, and an indication of the experimental measurements which seem to me most needed to advance this branch of optical science. As the greater part of what has been done towards placing the theory of double refraction on a rigorous dynamical basis is subsequent to the date of Dr. Lloyd's admirable report on "Physical Optics," I have thought it best to take a review of the whole subject, though at the risk of repeating a little of what is already contained in that report.

The celebrated theory of Fresnel was defective in rigour in two respects, as Fresnel himself clearly perceived. The first is that the expression for the force of restitution is obtained on the supposition of the *absolute* displacement of a molecule, whereas in undulations of all kinds the forces of restitution with which we are concerned are those due to *relative* displacements. Fresnel endeavoured to show, by reasoning professedly only probable, that while the *magnitude* of the force of restitution is altered in passing from absolute to relative displacements, the *law* of the force as to its dependence on the direction of vibration remains the same. The other point relates to the neglect of the component of the force in a direction perpendicular to the front of a wave. In the state of things supposed in the calculation of the forces of restitution called into play by absolute displacements, there is no immediate recognition of a wave at all, and a molecule is supposed to be as free to move in one direction as in another. But a displacement in a direction perpendicular to the front of a wave would call into play new forces of restitution having a resultant not in general in the direction of displacement; so that even the component of the force of restitution in a direction parallel to the front of a wave would have an expression altogether different from that determined by the theory of Fresnel. But the absolute displacements are only considered for the sake of obtaining results to be afterwards applied to relative displacements; and Fresnel distinctly makes the supposition that the ether is incompressible, or at least is sensibly so under the action of forces comparable with those with which we are concerned in the propagation of light. This supposition removes the difficulty; and though it increases the number of hypotheses as to the existing state of things, it cannot be objected to in point of rigour, unless it be that a demonstration might be required that incompressibility is not inconsistent with the assumed constitution of the ether, according to which it is regarded as consisting of distinct material points, symmetrically arranged, and acting on one another with forces depending, for a given pair, only on the distance. Hence the neglect of the force perpendicular to the fronts of the waves is not so much a new defect of rigour, as the former defect appearing under a new aspect.

I have mentioned these points because sometimes they are slurred over, and Fresnel's theory spoken of as if it had been rigorous throughout, to the injury of students and the retardation of the real progress of science; and sometimes, on the other hand, the grand advance made by Fresnel is depreciated on account of his theory not being everywhere perfectly rigorous. If we reflect on the state of the subject as Fresnel found it, and as he left it, the wonder is, not that he failed to give a rigorous dynamical theory, but that a single mind was capable of effecting so much.

The first deduction of the laws of double refraction, or at least of an approximation to the true laws, from a rigorous theory is due to Cauchy*, though Neumann† independently, and almost simultaneously, arrived at the same results. In the theory of Cauchy and Neumann the ether is supposed to consist of distinct particles, regarded as material points, acting on one another by forces in the line joining them which vary as some function of the distances, and the arrangement of these particles is supposed to be different in different directions. The medium is further supposed to possess three rectangular planes of symmetry, the double refraction of crystals, so far as has been observed, being symmetrical with respect to three such planes. The equations of motion of the medium are deduced by a method similar to that employed by Navier in the case of an isotropic medium. The equations arrived at by Cauchy, the medium being referred to planes of symmetry, contain nine arbitrary constants, three of which express the pressures in the principal directions in the state of equilibrium. Those employed by Neumann contain only six such constants, the medium in its natural state being supposed free from pressure.

In the theory of double refraction, whatever be the particular dynamical conditions assumed, everything is reduced to the determination of the velocity of propagation of a plane wave propagated in any given direction, and the mode of vibration of the particles in such a wave which must exist in order that the wave may be propagated with a unique velocity. In the theory of Cauchy now under consideration, the direction of vibration and the reciprocal of the velocity of propagation are given in direction and magnitude respectively by the principal axes of a certain ellipsoid, the equation of which contains the nine arbitrary constants, and likewise the direction-cosines of the wave-normal. Cauchy adduces reasons for supposing that the three constants G, H, I, which express the pressures in the state of equilibrium, vanish, which leaves only six constants. For waves perpendicular to the principal axes, the squared velocities of propagation and the corresponding directions of vibration are given by the following Table:—

Wave-normal		x	y	z
Direction of vibration...........	x	L	R	Q
	y	R	M	P
	z	Q	P	N

For waves *in these directions*, then, the vibrations are either wholly normal or wholly transversal. The latter are those with which we have to deal in the theory of light. Now, according to observation, in any one of the principal planes of a doubly refracting crystal, that ray which is polarized in the principal plane obeys the ordinary law of refraction. In order therefore that the conclusions of this theory should at all agree with observation, we must suppose that in polarized light the vibrations are parallel, not perpendicular, to the plane of polarization.

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* Mémoires de l'Académie, tom. x. p. 293.

† Poggendorff's Annalen, vol. xxv. p. 418 (1832).

Let l, m, n be the direction-cosines of the wave-normal. In the theory of Cauchy and Neumann, the square v^2 of the velocity of propagation is given by a cubic of the form

$$v^6+\alpha_2 v^4+\alpha_4 v^2+\alpha_6=0,$$

where α_2, α_4, α_6 are homogeneous functions of the 1st order as regards L, M, N, P, Q, R, and homogeneous functions of the orders 2, 4, 6 as regards l, m, n, involving even powers only of these quantities. For a wave perpendicular to one of the principal planes, that of $y\,z$ suppose, the cubic splits into two rational factors, of which that which is of the first degree in v^2, namely,

$$v^2-m^2\,\mathrm{R}-n^2\,\mathrm{Q},$$

corresponds to vibrations perpendicular to the principal plane. This is the same expression as results from Fresnel's theory, and accordingly the section, by the principal plane, of one sheet of the wave-surface, which in this theory is a surface of three sheets, is an ellipse, and the law of refraction of that ray which is polarized perpendicularly to the principal plane agrees exactly with that given by the theory of Fresnel.

For the two remaining waves, the squared velocities of propagation are given by the quadratic

$$(v^2-m^2\,\mathrm{M}-n^2\,\mathrm{P})\,(v^2-m^2\,\mathrm{P}-n^2\,\mathrm{N})-4m^2n^2\,\mathrm{P}^2=0\,; \quad \ldots\ldots \quad (1)$$

but according to observation the ray polarized in the principal plane obeys the ordinary law of refraction. Hence (1) ought to be satisfied by $v^2-(m^2+n^2)\,\mathrm{P}=0$, which requires that $(\mathrm{M}-\mathrm{P})\,(\mathrm{N}-\mathrm{P})=4\mathrm{P}^2$, on which supposition the remaining factor must evidently be linear as regards m^2, n^2, and therefore must be

$$v^2-m^2\,\mathrm{M}-n^2\,\mathrm{N},$$

since it gives when equated to zero $v^2=\mathrm{M}$, or $v^2=\mathrm{N}$ for $m=1$, or $n=1$. And since the same must hold good for each of the principal planes, we must have the three following relations between the six constants,

$$(\mathrm{M}-\mathrm{P})\,(\mathrm{N}-\mathrm{P})=4\mathrm{P}^2\,;\ (\mathrm{N}-\mathrm{Q})\,(\mathrm{L}-\mathrm{Q})=4\mathrm{Q}^2\,;\ (\mathrm{L}-\mathrm{R})\,(\mathrm{M}-\mathrm{R})=4\mathrm{R}^2 \ldots (2)$$

The existence of six constants, of which only three are wanted to satisfy the numerical values of the principal velocities of propagation in a biaxal crystal, permits of satisfying these equations; so that the law that the ray polarized in the plane of incidence, when that is a principal plane, obeys the ordinary law of refraction is *not inconsistent* with Cauchy's theory. This simple law is, however, not in the slightest degree predicted by the theory, nor even rendered probable, nor have any physical conditions been pointed out which would lead to the relations (2); and, indeed, from the form of these equations, it seems hard to conceive what physical relations they could express. Hence an important desideratum would be left, even if the theory were satisfactory in all other respects.

The equation for determining v^2 virtually contains the theoretical laws of double refraction, which are embodied in the form of the wave-surface. The wave-surface of Cauchy and Neumann does not agree with that of Fresnel, except as the sections of two of its sheets by the principal planes, the third sheet being that which relates to nearly normal vibrations. Nevertheless the first two sheets, being forced to agree in their principal sections with Fresnel's surface, differ from it elsewhere extremely little. In Arragonite, for instance, in a direction equally inclined to the principal axes, assuming Rudberg's indices* for the line D, I find that the velocities of propagation of the two polarized waves, according to the theory of Cauchy and Neumann, differ from those resulting from the theory of Fresnel only in the *tenth* place of decimals, the velocity in air being taken as unity. Such a difference as this would of course be utterly insensible in experiment. In like manner the directions of the planes of polarization according to the two theories, though not rigorously, are extremely nearly the same, the plane of polarization of a wave in which the vibrations are nearly transversal being defined as that containing the direction of propagation and the direction of vibration, in harmony with the previously established definition for the case of strictly transversal vibrations.

Hence as far as regards the laws of double refraction of the two waves which *alone* are supposed to relate to the visible phenomenon, and of the accompanying polarization, this theory, *by the aid of the forced relations* (2), is very successful. I am not now discussing the generality, or, on the contrary, the artificially restricted nature, of the fundamental suppositions as to the state of things, but only the degree to which the results are in accordance with observed facts. But as regards the third wave the case is very different. That theory should point to the necessary existence of such a wave consisting of strictly normal vibrations, and yet to which no known phenomenon can be referred, is bad enough; but in the present theory the vibrations are not even strictly normal, except for waves in a direction perpendicular to any one of the principal axes. In Iceland spar, for instance, for waves propagated in a direction inclined 45° to the axis, it follows from the numerical values of the refractive indices for the fixed line D given by Rudberg that the two vibrations in the principal plane which can be propagated independently of each other are inclined at angles of 9° 50′ and 80° 10′, or say 10° and 80°, to the wave-normal. We can hardly suppose that a mere change of inclination in the direction of vibration of from 10° to 80° with the wave front makes all the difference whether the wave belongs to a long-known and evident phenomenon, no other than the ordinary refraction in Iceland spar, or not to any visible phenomenon at all.

It is true that before there can be any question of the third wave's being perceived it must be supposed excited, and the means of exciting it consist in the incident vibrations in air, which by hypothesis are strictly transversal. Hence we have to inquire whether the intensity of the third wave is such as to lead us to expect a sensible phenomenon answering to it. This leads us to the still more uncertain subject of the intensity of light reflected or refracted at the surface of a crystal—more uncertain because it not only depends on the laws of internal propagation, and involves all the hypotheses on which these laws are theoretically deduced, but requires fresh hypotheses as to the state of things at the confines of two media, introducing thereby fresh elements of uncertainty. But for our present purpose no exact calculation of intensities is required; a rough estimate of the intensity of the nearly normal vibrations is quite sufficient.

In order to introduce as little as possible relating to the theory of the intensity of reflected and refracted light, suppose the incident light to fall perpendicularly on the surface of a crystal, and let this be a surface of Iceland spar cut at an inclination of 45° to the axis. For a cleavage plane the result would be nearly the same. Let the incident light be polarized, and the vibrations be in the principal plane, which therefore, according to the theory now under consideration, must be the plane of polarization. The incident vibrations are parallel to the surface, and accordingly inclined at angles of 9° 50′ and 80° 10′ to the directions of the nearly transversal and nearly normal vibrations, respectively, within the crystal. Hence it seems evident that the amplitude of the latter must be of the order of magnitude of sin 9° 50′, or about $\frac{1}{5 \cdot 9}$, the amplitude of vibration in the incident light being taken as unity. The velocity of propagation of the nearly normal vibrations being to that of the nearly transversal roughly as $\sqrt{3}$ to 1, as will immediately be shown, it follows that the *vis viva* of the nearly normal would be to that of the nearly transversal vibrations in a ratio comparable with that of $\sqrt{3} \times \sin^2 9° 50'$ to 1, or about $\frac{1}{26}$ to 1. Hence the intensity of the nearly normal vibrations is by no means insignificant, and therefore it is a very serious objection to the theory that no corresponding phenomenon should have been discovered. It has been suggested by some of the advocates of this theory that the normal vibrations may correspond to heat. But the fact of the polarization of heat at once negatives such a supposition, even without insisting on the accumulation of evidence in favour of the identity of radiant heat and light of the same refrangibility.

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* Annales de Chimie, tom. xlviii. p. 254 (1831).

But the objections to the theory on the ground of the absence of some unknown phenomenon corresponding with the third ray, to which the theory necessarily conducts, are not the only ones which may be urged against it in connexion with that ray. The existence of normal or nearly normal vibrations entails consequences respecting the transversal which could hardly fail to have been detected by observation. In the first place, the *vis viva* belonging to the normal vibrations is so much abstracted from the transversal, which alone by hypothesis constitute light, so that there is a loss of light inherent in the very act of passage from air into the crystal, or conversely, from the crystal into air. About $\frac{1}{26}$th of the whole might thus be expected to be lost at a single surface of Iceland spar, the surface being inclined 45° to the axis, and the light being incident perpendicularly, and being polarized in the principal plane; and the loss would amount to somewhere about $\frac{1}{13}$th in passage across a plate bounded by parallel surfaces, by which amount the sum of the reflected and transmitted light ought to fall short of the incident. And it is evident that something of the same kind must take place at other inclinations to the axis and at other incidences. The loss thus occasioned in multiplied reflexions could hardly have escaped observation, though it is not quite so great as might at first sight appear, as the transversal vibrations produced back again by the normal would presently become sensible.

But the most fatal objection of all is that urged by Green* against the supposition that normal vibrations could be propagated with a velocity comparable with those of transversal. As transversal vibrations are capable (according to the suppositions here combated) of giving rise at incidence on a medium to normal or nearly normal vibrations within it, so conversely the latter on arriving at the second surface are capable of giving rise to emergent transversal vibrations; so that not only would normal vibrations entail a loss of light in the quarter in which light is looked for, but would give rise to light (of small intensity it is true, but by no means imperceptible) in a quarter in which otherwise there would have been none at all. Thus in the case supposed above, the intensity of the light produced by nearly normal vibrations giving rise on emergence to transversal vibrations would be somewhere about the $(\frac{1}{26})^2$ or the $\frac{1}{676}$ of the incident light. In the case of light transmitted through a plate, the rays thus produced would be parallel to the incident, or to the emergent rays of the kind usually considered; but if the plate were wedge-shaped the two would come out in different directions, and with sunlight the former could not fail to be perceived. The only way apparently of getting over this difficulty, is by making the perfectly gratuitous assumption that the medium, though perfectly transparent for the more nearly transversal vibrations, is intensely opaque for those more nearly normal.

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* Cambridge Philosophical Transactions, vol. vii. p. 2.

Lastly, Green's argument respecting the necessity of supposing the velocity of propagation of normal vibrations very great has here full force as an objection against this theory. The constants P, Q, R are the squared reciprocals of the three principal indices of refraction, which are given by observation, and L, M, N are determined in terms of P, Q, R by the equations (2), by the solution of a quadratic equation. In the case of a uniaxal crystal everything is symmetrical about one of the axes, suppose that of z, which requires, as Cauchy has shown, that $L=M=3R$, and $P=Q$; and of the equations (2) one is now satisfied identically, and the two others are identical with each other, and give

$$N=P+\frac{4P^2}{3R-P}.$$

For an isotropic medium we must have $L=M=N=3P=3Q=3R$, and the three equations (2) are satisfied identically. The velocity of propagation of normal must be to that of transversal vibrations as $\sqrt{3}$ to 1, and cannot therefore be assumed to be what may be convenient for explaining the law of intensity of reflected light.

The theory which has just been discussed is essentially bound up with the supposition that in polarized light the vibrations are parallel, not perpendicular, to the plane of polarization. In prosecuting the study of light, Cauchy saw reason to change his views in this respect, and was induced to examine whether his theory could not be modified so as to be in accordance with the latter alternative. The result, constituting what may be called Cauchy's second theory, is contained in a memoir read before the Academy, May 20, 1839*. In this he refers to his memoir on dispersion, in which the fundamental equations are obtained in a manner somewhat different from that given in his 'Exercices,' but based on the same suppositions as to the constitution of the ether. In the new theory Cauchy retains the three constants G, H, I, expressing the pressures in equilibrium, which formerly he made vanish, the medium being supposed as before to be symmetrical with respect to three rectangular planes. The squares of the velocities of propagation, and the corresponding directions of vibration for the three waves which can be propagated in the direction of each of the principal axes, are given by the following Table.

Wave-normal................		x	y	z
Direction of vibration...........	x	$L+G$	$R+H$	$Q+I$
	y	$R+G$	$M+H$	$P+I$
	z	$Q+G$	$P+H$	$N+I$

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* "Sur la Polarisation rectiligne, et la double Réfraction," Mém. de l'Académie, tom. xviii. p. 153.

According to observation, in each of the principal planes the ray polarized in that plane obeys the ordinary law of refraction, and therefore if we suppose that in polarized light the vibrations, at least when strictly transversal, are perpendicular to the plane of polarization, we must assume that $R+H=Q+I$, $P+I=R+G$, $Q+G=P+H$, which are equivalent to only two distinct relations, namely

$$P-G=Q-H=R-I \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (3)$$

For a wave parallel to one of the principal axes, as that of x, the direction of that axis is one of the three rectangular directions of vibration of the waves which are propagated independently. For such vibrations the velocity (v) of propagation is given by the formula

$$v^2=m^2(R+H)+n^2(Q+I),$$

which by (3) is reduced to

$$v^2=R+H=Q+I,$$

so that on the assumption that the velocity of propagation is the same for a wave perpendicular to the axis of y as for one perpendicular to the axis of z when the vibrations are parallel to the axis of x, the law of ordinary refraction in the plane of yz follows from theory.

For the two remaining waves which can be propagated independently in a given direction perpendicular to the axis of x, the vibrations are only approximately normal and transversal respectively. In fact, for the three waves which can travel independently in any given direction, the directions of vibration are not affected by the introduction of the constants expressing equilibrium-pressures, but only the velocities of propagation. The squares of the velocities of propagation of the two waves above mentioned are given as before by a quadratic; and in order that the velocity of propagation of the nearly transversal vibrations may be expressed by the formula

$$v^2=c^2m^2+b^2n^2 \ldots \ldots \ldots \ldots \ldots \ldots \quad (4),$$

in conformity with the ellipsoidal form of the extraordinary wave surface in a uniaxal crystal, and the assumed elliptic form of the section of one sheet of the wave-surface in a biaxal crystal by a principal plane, the quadratic in question must split into two rational factors, which leads to precisely the same condition as before, namely that expressed by the first of equations (2); and by equating to zero the corresponding factor, we get

$$v^2=(P+H)m^2+(P+I)n^2,$$

which is in fact of the form (4). Applying the same to each of the other principal axes, we find again the three relations (2).

Hence Cauchy's second theory, in which it is supposed that in polarized light the vibrations (in air or in an isotropic medium) are *perpendicular* to the plane of polarization, leads like the first to laws of double refraction, and of the accompanying polarization, differing from those of Fresnel only by quantities which may be deemed insensible. This result is, however, in the present case only attained by the aid of *two* sets of forced relations, namely (2) and (3), that is, relations which there is nothing *à priori* to indicate, and which are not the expression of any simple physical idea, but are obtained by *forcing* the theory, which in its original state is of a highly plastic nature from the number of arbitrary constants which it contains, to agree with observation in some particulars, which being done, theory by itself makes known the rest. As regards the third ray by which this theory like its predecessor is hampered, there is nearly as much to be urged against the present theory as the former. There is, however, this difference, that, as there are only five relations, (2) and (3), between nine arbitrary constants, there remains one arbitrary constant in the expressions for the velocities of propagation after satisfying the numerical values of the three principal indices of refraction, by a proper disposal of which the objections which have been mentioned may *to a certain extent* be lessened, but by no means wholly overcome.

I come now to Green's theory, contained in a very remarkable memoir "On the Propagation of Light in Crystallized Media," read before the Cambridge Philosophical Society, May 20, 1839*, and accordingly, by a curious coincidence, the very day that Cauchy's second theory was presented to the French Academy. Besides the great interest of the memoir in relation to the theory of light, Green has in it, as I conceive, given for the first time the true equations of equilibrium and motion of a homogeneous elastic solid slightly disturbed from its position of equilibrium, which is one of constraint under a uniform pressure different in different directions. In a former memoir† he had given the equations for the case in which the undisturbed state is one free from pressure‡. When I speak of the true equations, I mean the equations which belong to the problem when not restricted in generality by arbitrarily assumed hypotheses, and yet not containing constants which are incompatible with any well-ascertained physical principle. It is right to mention, however, that on this point mathematicians are not agreed; M. de Saint-Venant, for instance, maintains the justice of the more restricted equations given by Cauchy§, though even he would not conceive the latter equations applicable to such solids as caoutchouc or jelly.

In these papers Green introduced into the treatment of the subject, with the greatest advantage, the method of Lagrange, in which the partial differential equations of motion are obtained from the variation of a single force-function, on the discovery of the proper form of which everything turns. Green's principle is thus enunciated by him:—"In whatever manner the elements of any material system may act on each other, if all the internal forces be multiplied by the elements of their respective directions, the total sum for any assigned portion of the mass will always be the exact differential of some function." In accordance with this principle, the general equation may be put under the form

$$\iiint \rho\, dx\, dy\, dz \left(\frac{d^2u}{dt^2}\,\delta u+\frac{d^2v}{dt^2}\,\delta v+\frac{d^2w}{dt^2}\,\delta w\right)=\iiint dx\, dy\, dz\, \delta\phi \quad . \quad (5),$$

where x, y, z are the equilibrium coordinates of any particle, ρ the density in equilibrium, u, v, w the displacements parallel to x, y, z, and ϕ the function in question. ϕ is in fact the function the variation of which in passing from one state of the medium to another, when multiplied by $dx\,dy\,dz$, expresses the work given out by the portion of the medium occupying in equilibrium the elementary parallelepiped $dx\,dy\,dz$, in passing from the first state to the second. The portion of the medium which in the state of equilibrium occupied the elementary parallelepiped becomes in the changed state an oblique-angled parallelepiped, whose edges may be represented by $dx\,(1+s_1)$, $dy\,(1+s_2)$, $dz\,(1+s_3)$, and the cosines of the angles between the second and third, third and first, and first and second of these edges by α, β, γ, which in case the disturbance be small will be small quantities only. It is manifest that the function ϕ must be independent of any linear or angular displacement of the element $dx\,dy\,dz$, and depend only on the change of form of the element, and therefore on the six quantities $s_1, s_2, s_3, \alpha, \beta, \gamma$, which may be expressed by means of the nine differential coefficients of u, v, w with respect to x, y, z, of which therefore ϕ is a function, but not any function, since it involves not nine, but only six independent variables. If the disturbance be small, the six quantities $s_1, s_2, s_3, \alpha, \beta, \gamma$ will be small likewise, and ϕ may be expressed in a convergent series of the form

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* Cambridge Philosophical Transactions, vol. vii. p. 120.

† "On the Reflexion and Refraction of Light," Cambr. Phil. Trans. vol. vii. p. 1. Read Dec. 11, 1837.

‡ They are virtually given, though not actually written down at length.

§ Comptes Rendus, tom. liii. p. 1105 (1861).

$$\phi=\phi_0+\phi_1+\phi_2+\phi_3+\ldots,$$

where $\phi_0, \phi_1, \phi_2, \phi_3$, &c. are homogeneous functions of the six quantities, of the orders 0, 1, 2, 3, &c.; and if the motion be regarded as indefinitely small, the functions $\phi_3, \phi_4 \ldots$ will be insensible, the left-hand member of equation (5) being of the second order as regards u, v, w. ϕ_0, being a constant, will not appear in equation (5), and ϕ_1 will be equal to zero in case the medium in its undisturbed state be free from internal pressure, but not otherwise. The function ϕ_2, being a homogeneous function of six independent variables of the second order, contains in its most general shape twenty-one arbitrary constants, and ϕ_1 which is of the first order introduces six more, so that the most general expression for ϕ contains no less than twenty-seven arbitrary constants, all which appear in the expressions for the internal pressures and in the partial differential equations of motion*.

The general expressions for the internal tensions in an elastic medium and the general equations of equilibrium or motion which were given by Cauchy, and which are written at length in the 4th volume of the 'Exercices de Mathématiques,' contain twenty-one arbitrary constants when the undisturbed state of the medium is one of uniform constraint, and fifteen when it is one of freedom from pressure. In the latter case, Green's twenty-one constants are reduced to two, and Cauchy's fifteen to only one, when the medium is isotropic. Green's equations comprise Cauchy's as a particular case, as will be shown more at length further on. It becomes an important question to inquire whether Cauchy's equations involve some restrictive hypothesis as to the constitution of the medium, so as to be in fact of insufficient generality, or whether, on the other hand, Green's equations are reducible to Cauchy's by the introduction of some well-ascertained physical principle, and therefore contain redundant constants.

In the formation of Cauchy's equations, not only is the medium supposed to consist of material points acting on one another by forces which depend on the distance only (a supposition which, at least when coupled with the next, excludes the idea of molecular polarity), but it is assumed that the displacements of the *individual molecules* vary from molecule to molecule according to the variation of some continuous function of the coordinates; and accordingly the displacements u', v', w' of the molecule whose coordinates in equilibrium are $x+\Delta x, y+\Delta y, z+\Delta z$ are expanded by Taylor's theorem in powers of $\Delta x, \Delta y, \Delta z$, and the differential coefficients $\frac{du}{dx}$, &c. are put outside the sign of summation. The motion, varying from point to point, of the medium taken as a whole, or in other words the *mean* motion, in any direction, of the molecules in the neighbourhood of a given point, must not be confounded with the motion of the molecules *taken individually*. The medium being continuous, so far as anything relating to observation is concerned, the former will vary continuously from point to point. But it by no means follows that the motion of the molecules considered individually should vary from one to another according to some function of the coordinates. The motion of the individual molecules is only considered for the sake of deducing results from hypotheses as to the molecular constitution and molecular forces of the medium, and in it we are concerned only with the *relative* motion of molecules situated so close as to act sensibly on each other. It would seem to be very probable, *à priori*, that a portion by no means negligible of the relative displacement of a pair of neighbouring molecules should vary in an irregular manner from pair to pair; and indeed if the medium tends to relieve itself from a state of constrained distortion, this must necessarily be the case; and such a rearrangement must assuredly take place in fluids. The insufficient generality of Cauchy's equations is further shown by their being *absolutely incompatible* with the idea of incompressibility. We may evidently conceive a solid which resists compression of volume by a force incomparably greater than that by which it resists distortion of figure, and such a conception is actually realized in such a solid as caoutchouc or jelly.

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* The twenty-seven arbitrary constants enter the equations of motion in such a manner as to be there equivalent to only twenty-six distinct constants, the physical interpretation of which analytical result will be found to be that a uniform pressure alike in all directions, in the undisturbed state of the medium, produces the same effect on the internal movements when the medium is disturbed as a certain internal elasticity, alike in all directions, and of a very simple kind, which is possible in a medium unconstrained in its natural state. The twenty-one arbitrary constants belonging to a medium unconstrained in its natural state are not reducible in the equations of motion, any more than in the expressions for the internal tensions, to a smaller number.

I have not mentioned the hypothesis of what may be called, from the analogy of surfaces of the second order, a *central* arrangement of the molecules, that is, an arrangement such that each molecule is a centre with respect to which the others are arranged in pairs at equal distances in opposite directions, because the hypothesis was merely casually introduced as one mode of making certain terms vanish which are of a form that clearly ought not to appear in the expressions relating to the mean motion, with which alone we are ultimately concerned.

The arguments in favour of the existence of ultimate molecules in the case of ponderable matter appear to rest chiefly on the chemical law of definite proportions, and on the laws of crystallography, neither of which of course can be assumed to apply to the mysterious ether, of the very existence of which we have no direct evidence. If, for aught we know to the contrary, the very supposition of the existence of ultimate molecules as applied to the ether may entail consequences at variance with its real constitution, much more must the accessory hypotheses be deemed precarious which Cauchy found necessary in order to be able to deduce any results at all in proceeding by his method. There appears, therefore, no sufficient reason *à priori* for preferring the more limited equations of Cauchy to the more general equations of Green.

Green, on the other hand, takes his stand on the impossibility of perpetual motion, or in other words, on the principle of the conservation of work, which we have the strongest reasons for believing to be a general physical principle*. The number of arbitrary constants thus furnished in the case in which the undisturbed state of the medium is one of freedom from pressure is, as has been stated, twenty-one. Professor Thomson has recently put this result in a form which indicates more clearly the signification of the constants†, and at the end of his memoir promises to show how an elastic solid,

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[*] Whether vital phenomena are subject to this law is a question which we are not here called upon to discuss.

[†] "Elements of a Mathematical Theory of Elasticity," Phil. Trans. for 1856, p. 481. Read April 24, 1856.

which as a whole should possess this number of arbitrary constants, could be built up of isotropic matter.

Green supposes, in the first instance, that the medium is symmetrical with respect to planes in three rectangular directions, which simplifies the investigation and reduces the twenty-seven or twenty-one arbitrary constants to twelve (entering the partial differential equations of motion in such a manner as to be there equivalent to only eleven) or nine. It may be useful to give a Table of the constants employed by Green, with their equivalents in the theories of Cauchy and Neumann, the density of the medium at rest being taken equal to unity for the sake of simplicity. The Table is as follows:—

Green	A B C	G H I	L M N	P Q R
Cauchy	G H I	L M N	P Q R	P Q R
Neumann	0 0 0	D C B	$A_{,}$ A $A_{,,}$	$A_{,}$ A $A_{,,}$;

so that Green's equations are reduced to Cauchy's by making

$$L=P, \qquad M=Q, \qquad N=R. \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

For a plane wave propagated in any given direction there are three velocities of propagation, and three corresponding directions of vibration, which are determined by the directions of the principal axes of a certain ellipsoid $U=1$, which he proposes to call the ellipsoid of elasticity, the semiaxes at the same time representing in magnitude the squared reciprocals of the corresponding velocities of propagation; and Green has shown that U may be at once obtained from the function -2ϕ by taking that part only which is of the second order in u, v, w, and replacing u, v, w by x, y, z, and the symbols of differentiation $\frac{d}{dx}, \frac{d}{dy}, \frac{d}{dz}$ by the cosines of the angles which the wave-normal makes with the axes. This applies whether the medium be symmetrical or not with respect to the coordinate planes. Green then examines the consequences of supposing that for two of the three waves the vibrations are *strictly* in the front of the wave, as was supposed by Fresnel, and consequently that the vibrations belonging to the third wave are strictly normal. This hypothesis leads to five relations between the twelve constants, namely

$$G=H=I=\mu \text{ suppose}, \quad P=\mu-2L, \quad Q=\mu-2M, \quad R=\mu-2N; \quad . \quad (7)$$

and gives for the form of the fundamental function

$$\begin{aligned} -2\phi = {} & 2A\frac{du}{dx}+2B\frac{dv}{dy}+2C\frac{dw}{dz} \\ & +A\left\{\left(\frac{du}{dx}\right)^2+\left(\frac{dv}{dx}\right)^2+\left(\frac{dw}{dx}\right)^2\right\}+B\left\{\left(\frac{du}{dy}\right)^2+\left(\frac{dv}{dy}\right)^2+\left(\frac{dw}{dy}\right)^2\right\} \\ & +C\left\{\left(\frac{du}{dz}\right)^2+\left(\frac{dv}{dz}\right)^2+\left(\frac{dw}{dz}\right)^2\right\}+\mu\left(\frac{du}{dx}+\frac{dv}{dy}+\frac{dw}{dz}\right)^2 \\ & +L\left\{\left(\frac{dv}{dz}+\frac{dw}{dy}\right)^2-4\frac{dv}{dy}\frac{dw}{dz}\right\}+M\left\{\left(\frac{dw}{dx}+\frac{du}{dz}\right)^2-4\frac{dw}{dz}\frac{du}{dx}\right\} \\ & +N\left\{\left(\frac{du}{dy}+\frac{dv}{dx}\right)^2-4\frac{du}{dx}\frac{dv}{dy}\right\}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8) \end{aligned}$$

from which the equations of motion, the expressions for the internal pressures, and the equation of the ellipsoid of elasticity may be at once written down.

The simpler case in which the medium in its natural state is supposed free

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from pressure is first considered*. Green shows that the ellipse which is the section of the ellipsoid of elasticity by a diametral plane, parallel to the wave's front, if turned 90° in its own plane, belongs to a fixed ellipsoid, which gives at once Fresnel's elegant construction for the velocity of propagation and direction of the plane of polarization; but it is necessary to suppose that in polarized light the vibrations are parallel, not perpendicular, to the plane of polarization.

The general case in which the medium is not assumed to be symmetrical with respect to three rectangular planes, and in which therefore ϕ contains twenty-one arbitrary constants, is afterwards considered; and it is shown that the hypothesis of strict transversality leads to fourteen relations between them, leaving only seven constants arbitrary. But the function obtained on the assumption of planes of symmetry contains no fewer, for the four constants relating to these planes would be increased by three when the medium was referred to general axes. Hence therefore the existence of planes of symmetry is not an independent assumption, as in Cauchy's theory, but follows as a result.

In this beautiful theory, therefore, we are presented with no forced relations like Cauchy's equations; the result follows from the hypothesis of strictly transversal vibrations, to which Fresnel was led by physical considerations. The constant μ remains arbitrary, and it is easy to see that this constant expresses the square of the velocity of propagation of normal vibrations. Were this velocity comparable with the velocity of propagation of transversal vibrations, theory would lead us still to expect normal vibrations to be produced by light incident obliquely, though not by light incident perpendicularly, on the surface of a crystal, and the theory would still be exposed to many of the objections which have been already brought forward. But nothing hinders us from supposing, in accordance with the argument contained in Green's former paper, that μ is very great or sensibly infinite, which removes all the difficulty, since the motion corresponding to this term in the expression for $-2\,\phi$ would not be sensible except at a distance from the surface comparable with the length of a wave of light. Hence, although it might be said, so long as μ was supposed arbitrary, that the supposition of rigorous transversality had still something in it of the nature of a forced relation between constants, we see that the *single* supposition of incompressibility (under the action of forces at least comparable with those acting in the propagation of light)—the original supposition of Fresnel—introduced into the general equations, suffices to lead to the complete laws of double refraction as given by Fresnel. Were it not that other phenomena of light lead us rather to the conclusion that the vibrations are perpendicular, than that they are parallel to the plane of polarization, this theory would seem to leave us nothing to desire, except to prove that we had a right to neglect the *direct* action of the ponderable molecules, and to treat the ether within a crystal as a single elastic medium, of which the elasticity was different in different directions.

In his paper on Reflexion, Green had adopted the supposition of Fresnel, that the vibrations are perpendicular to the plane of polarization. He was naturally led to examine whether the laws of double refraction could be explained on this hypothesis. When the medium in its undisturbed state is exposed to pressure differing in different directions, six additional constants are introduced into the function ϕ, or three in case of the existence of planes of symmetry to which the medium is referred. For waves perpendicular to the principal axes, the directions of vibration and squared velocities of propagation are as follows:—

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* The results obtained for this case remain the same if we suppose the medium in its undisturbed state to be subject to a pressure alike in all directions.

Wave-normal		x	y	z
Direction of vibration	x	G+A	N+B	M+C
	y	N+A	H+B	L+C
	z	M+A	L+B	I+C

Green assumes, in accordance with Fresnel's theory, and with observation if the vibrations in polarized light are supposed perpendicular to the plane of polarization, that for waves perpendicular to any two of the principal axes, and propagated by vibrations in the direction of the third axis, the velocity of propagation is the same. This gives three, equivalent to two, relations among the constants, namely,

$$A-L=B-M=C-N=\nu \text{ suppose}, \quad . \quad . \quad . \quad . \quad . \quad (9)$$

which are equivalent to Cauchy's equations (3). The conditions that the vibrations are strictly transversal and normal respectively do not involve the six constants expressing the pressures in equilibrium, and therefore remain the same as before, namely (7). Adopting the relations (7) and (9), Green proves that for the two transversal waves the velocities of propagation and the azimuths of the planes of polarization are precisely those given by the theory of Fresnel, the vibrations in polarized light being now supposed *perpendicular* to the plane of polarization.

As to the wave propagated by normal vibrations, the square of its velocity of propagation is easily shown to be equal to

$$\mu+Al^2+Bm^2+Cn^2;$$

and as the constant μ does not enter into the expression for the velocity of propagation of transversal vibrations, the same supposition as before, namely that the medium is rigorously or sensibly incompressible, removes all difficulty arising from the absence of any observed phenomenon answering to this wave.

The existence of planes of symmetry is here *in part* assumed. I say *in part*, because Green shows that the six constants, expressing the pressures in equilibrium, enter the equation of the ellipsoid of elasticity under the form K $(x^2+y^2+z^2)$, where K is a homogeneous function of the six constants of the first order, and involves likewise the cosines l, m, n. Hence the directions of vibration are the same as when the six constants vanish; the velocities of propagation alone are changed; and as the existence of planes of symmetry for the case in which the six constants vanish was demonstrated, it is only requisite to make the very natural supposition that the planes of symmetry which must exist as regards the directions of vibration, are also planes of symmetry as regards the pressure in equilibrium.

We see then that this theory, which may be called Green's second theory, is in most respects as satisfactory (assuming for the present that Fresnel's construction does represent the laws of double refraction) as the former. I say *in most respects*, because, although the theory is perfectly rigorous, like the former, the equations (9) are of the nature of forced relations between the constants, not expressing anything which could have been foreseen, or even conveying when pointed out the expression of any simple physical relation.

The year 1839 was fertile in theories of double refraction, and on the 9th of December Prof. MacCullagh presented his theory to the Royal Irish Academy. It is contained in "An Essay towards a Dynamical Theory of Crystalline Reflexion and Refraction"[*]. As indicated by the title, the determination of the intensities of the light reflected and refracted at the surface of a crystal is what the author had chiefly in view, but his previous researches had led him to observe that this determination was intimately connected with the laws of double refraction, and to seek to link together these laws as parts of the same system. He was led to apply to the problem the general equation of dynamics under the form (5), to seek to determine the form of the function ϕ (V in his notation), and then to form the partial differential equations of motion, and the conditions to be satisfied at the boundaries of the medium, by the method of Lagrange. He does not appear to have been aware at the time that this method had previously been adopted by Green. Like his predecessors, he treats the ether within a crystallized body as a single medium unequally elastic in different directions, thus ignoring any *direct* influence of the ponderable molecules in the vibrations. He assumes that the density of the ether is a constant quantity, that is, both unchanged during vibration, and the same within all bodies as in free space. We are not concerned with the latter of these suppositions in deducing the laws of internal vibrations, but only in investigating those which regulate the intensity of reflected and refracted light. He assumes further that the vibrations in plane waves, propagated within a crystal, are rectilinear, and that while the plane of the wave moves parallel to itself the vibrations continue parallel to a fixed right line, the direction of this right line and the direction of a normal to the wave being functions of each other,—a supposition which doubtless applies to all crystals except quartz, and those which possess a similar property.

In this method everything depends on the correct determination of the form of the function V. From the assumption that the density of the ether is unchanged by vibration, it is readily shown that the vibrations are entirely transversal. Imagine a system of plane waves, in which the vibrations are parallel to a fixed line in the plane of a wave, to be propagated in the crystal, and refer the crystal for a moment to the rectangular axes of x', y', z', the plane of $x'y'$ being parallel to the planes of the waves, and the axis of y' to the direction of vibration; and let κ be the angle whose tangent is $\frac{d\eta'}{dz'}$. With respect to the form of V, MacCullagh reasons thus:—"The function V can only depend upon the directions of the axes of x', y', z' with respect to fixed lines in the crystal, and upon the angle which measures the change of form produced in the parallelepiped by vibration. This is the most general supposition which can be made concerning it. Since, however, by our second supposition, any one of these directions, suppose that of x', determines the other two, we may regard V as depending on the angle κ and the direction of the axis of x' alone," from whence he shows that V must be a function of the quantities X, Y, Z, defined by the equations

$$\mathrm{X}=\frac{d\eta}{dz}-\frac{d\zeta}{dy},\quad \mathrm{Y}=\frac{d\zeta}{dx}-\frac{d\xi}{dz},\quad \mathrm{Z}=\frac{d\xi}{dy}-\frac{d\eta}{dx}.$$

This reasoning, which is somewhat obscure, seems to me to involve a fallacy.

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[*] Memoirs of the Royal Irish Academy, vol. xxi. p. 17.

If the form of V were known, the rectilinearity of vibration and the constancy in the direction of vibration for a system of plane waves travelling in any given direction would follow as a *result* of the solution of the problem. But in using equation (5) we are not at liberty to substitute for V (or ϕ) an expression which represents that function *only on the condition that the motion be what it actually is*, for we have occasion to take the variation δV of V, and this variation must be the most general that is geometrically possible though it be dynamically impossible. That the form of V, arrived at by MacCullagh, is inadmissible, is, I conceive, proved by its incompatibility with the form deduced by Green from the very same supposition of the *perfect* transversality of the transversal vibrations; for Green's reasoning is perfectly straightforward and irreproachable. Besides, MacCullagh's form leads to consequences absolutely at variance with dynamical principles*.

But waiving for the present the objection to the conclusion that V is a function of the quantities X, Y, Z, let us follow the consequences of the theory. The disturbance being supposed small, the quantities X, Y, Z will also be small, and V may be expanded in a series according to powers of these quantities; and, as before, we need only proceed to the second order if we regard the disturbance as indefinitely small. The first term, being merely a constant, may be omitted. The terms of the first order MacCullagh concludes must vanish. This, however, it must be observed, is only true on the supposition that the medium in its undisturbed state is free from pressure. The terms of the second order are six in number, involving squares and products of X, Y, Z. The terms involving YZ, ZX, XY may be got rid of by a transformation of coordinates, when V will be reduced to the form

$$V=-\tfrac{1}{2}(a^2X^2+b^2Y^2+c^2Z^2), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

the constant term being omitted, and the arbitrary constants being denoted by $-\frac{1}{2}a^2$, $-\frac{1}{2}b^2$, $-\frac{1}{2}c^2$. Thus on this theory the existence of principal axes is proved, not assumed. If MacCullagh's expression for V (10) be compared with Green's expression for ϕ (8) for the case of no pressure in equilibrium, so that A=0, B=0, C=0, it will be seen that the two will become identical, provided first we omit the term $\mu\left(\frac{du}{dx}+\frac{dv}{dy}+\frac{dw}{dz}\right)^2$ in Green's expression, and secondly, we treat the symbols of differentiation as literal coefficients, so as to confound, for instance, $\frac{dv}{dy}\frac{dw}{dz}$ and $\frac{dv}{dz}\frac{dw}{dy}$. The term involving μ does not appear in the expressions for transversal vibrations, since for these $\frac{du}{dx}+\frac{dv}{dy}+\frac{dw}{dz}=0$, and therefore does not affect the laws of the propagation of such vibrations, although it would appear in the problem of calculating the intensity of reflected and refracted light; and be that as it may, it follows from Green's rule for forming the equation of the ellipsoid of elasticity, that the laws of the propagation of transversal vibrations will be precisely the same whether we adopt his form of ϕ or V (for the case of no pressure in equilibrium) or MacCullagh's. Indeed, if we omit the term $\mu\left(\frac{du}{dx}+\frac{dv}{dy}+\frac{dw}{dz}\right)^2$, the partial differential equations of motion, on which alone depend the laws of internal propagation, would be just the same as the two theories†. Accordingly MacCullagh obtained, though independently of, and in a different manner from Green, precisely Fresnel's laws of double refraction and the accompanying polarization, on the condition, however, that in polarized light the vibrations are *parallel to* the plane of polarization.

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* See Appendix.

† See Appendix. MacCullagh's reasoning appears to be so far correct as to have led to correct equations, although through a form of V which may, I conceive, be shown to be inadmissible.

It is remarkable that in the previous year MacCullagh, in a letter to Sir David Brewster*, published expressions for the internal pressures identical with those which result from Green's first theory, provided that in the latter the terms be omitted which arise from that term in ϕ which contains μ, a term which vanishes in the case of transversal vibrations propagated within a crystal. It does not appear how these expressions were obtained by MacCullagh; it was probably by a tentative process.

The various theories which have just been reviewed have this one feature in common, that in all, the direct action of the ponderable molecules is neglected, and the ether treated as a single vibrating medium. It was, doubtless, the extreme difficulty of determining the motion of one of two mutually penetrating media that led mathematicians to adopt this, at first sight, unnatural supposition; but the conviction seems by some to have been entertained from the first, and to have forced itself upon the minds of others, that the ponderable molecules must be taken into account in a far more direct manner. Some investigations were made in this direction by Dr. Lloyd as long as twenty-five years ago†. Cauchy's later papers show that he was dissatisfied with the method, adopted in his earlier ones, of treating the ether within a ponderable body as a single vibrating medium‡; but he does not seem to have advanced beyond a few barren generalities, towards a theory of double refraction founded on a calculation of the vibrations of one of two mutually penetrating media. In the theory of double refraction advanced by Professor Challis§, the ether is assimilated to an ordinary elastic fluid, the vibrations of which are modified by resisting masses; and his theory leads him at once to Fresnel's elegant construction of the wave surface by points. The theory, however, rests upon principles which have not received the general assent of mathematicians. In a work entitled "Light explained on the Hypothesis of the Ethereal Medium being a Viscous Fluid"‖, Mr. Moon has put in a clear form some of the more serious objections which may be raised against Fresnel's theory; but that which he has substituted is itself open to formidable objections, some of which the author himself seems to have perceived.

In concluding this part of the subject, I may perhaps be permitted to express my own belief that the true dynamical theory of double refraction has yet to be found.

In the present state of the theory of double refraction, it appears to be of especial importance to attend to a rigorous comparison of its laws with actual observation. I have not now in view the two great laws giving the planes of polarization, and the difference of the squared velocities of propagation, of the two waves which can be propagated independently of each other in any given direction within a crystal. These laws, or at least laws differing from them only by quantities which may be deemed negligible in observation, had previously been discovered by experiment; and the deduction of these laws by Fresnel from his theory, combined with the verification of the law, which his theory, correcting in this respect previous notions, first pointed out, that in each principal plane of a biaxal crystal the ray polarized in that plane obeys the ordinary law of refraction, leaves no reasonable doubt that Fresnel's construction contains the true laws of double refraction, at least in their broad features. But regarding this point as established, I have rather in view a verification of those laws which admit of being put to the test of experiment with extreme precision; for such verifications might often enable the mathematician, in groping after the true theory, to discard at once, as not agreeing with observation, theories which might present themselves to his mind, and on which otherwise he might have spent much fruitless labour.

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* Philosophical Magazine for 1836, vol. viii. p. 103.

† Proceedings of the Royal Irish Academy, vol. i. p. 10.

‡ See his optical memoirs published in the 22nd volume of the 'Mémoires de l'Académie.'

§ Cambridge Philosophical Transactions, vol. viii. p. 524.

‖ Macmillan & Co., Cambridge, 1853.

To make my meaning clearer, I will refer to Fresnel's construction, in which the laws of polarization and wave-velocity are determined by the sections, by a diametral plane parallel to the wave-front, of the ellipsoid*

$$a^2x^2+b^2y^2+c^2z^2=1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11),$$

where a, b, c denote the principal wave-velocities. The principal semiaxes of the section determine by their direction the normals to the two planes of polarization, and by their magnitude the reciprocals of the corresponding wave-velocities. Now a certain other physical theory which might be proposed leads to a construction differing from Fresnel's only in this, that the planes of polarization and wave-velocities are determined by the section, by a diametral plane parallel to the wave-front, of the ellipsoid

$$\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}=1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12),$$

the principal semiaxes of the section determining by their direction the normals to the two planes of polarization, and by their magnitudes the corresponding wave-velocities. The law that the planes of polarization of the two waves propagated in a given direction bisect respectively the two supplemental dihedral angles made by planes passing through the wave-normal and the two optic axes, remains the same as before, but the positions of the optic axes themselves, as determined by the principal indices of refraction, are somewhat different; the difference, however, is but small if the differences between a^2, b^2, c^2 are a good deal smaller than the quantities themselves. Each principal section of the wave surface, instead of being a circle and an ellipse, is a circle and an oval, to which an ellipse is a near approximation†. The difference between the inclinations of the optic axes, and between the amounts of extraordinary refraction in the principal planes, on the two theories, though small, are quite sensible in observation, but only on condition that the observations are made with great precision. We see from this example of what great advantage for the advancement of theory observations of this character may be.

One law which admits of receiving, and which has received, this searching comparison with observation, is that according to which, in each principal plane of a biaxal crystal, the ray which is polarized in that plane obeys the ordinary law of refraction, and accordingly in a uniaxal crystal, in which every plane parallel to the axis is a principal plane, the so-called ordinary ray follows rigorously the law of ordinary refraction. This law was carefully verified by Fresnel himself in the case of topaz, by the method of cutting plates parallel to the same principal axis, or axis of elasticity, carefully

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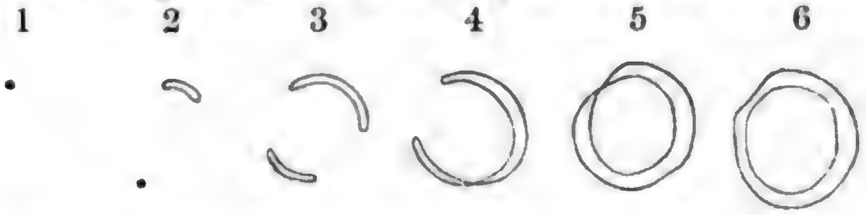
[*] It would seem to be just as well to omit the surface of elasticity altogether, and refer the construction directly to the ellipsoid (11).

[†] The equation of the surface of wave-slowness in this and similar cases may be readily obtained by the method given by Professor Haughton in a paper "On the Equilibrium and Motion of Solid and Fluid Bodies," Transactions of the Royal Irish Academy, vol. xxi. p. 172.

working them to the same thickness, and then interposing them in the paths of two streams of light proceeding to interfere, as well as by the method of prismatic refraction; and he states as the result of his observations that he can affirm the law to be, at least in the case of topaz, mathematically exact. The same result follows from the observations by which Rudberg so accurately determined the principal indices of Arragonite and topaz[*], for the principal fixed lines of the spectrum. Professor MacCullagh having been led by theoretical considerations to doubt whether, in Iceland spar for instance, the so-called ordinary ray rigorously obeyed the ordinary law of refraction, whether the refractive indices in the axial and equatorial directions were *strictly* the same, Sir David Brewster was induced to put the question to the test of a crucial experiment, by forming a compound prism consisting of two pieces of spar cemented together in the direction of the length of the prism, and so cut from the crystal that at a minimum deviation one piece was traversed axially and the other equatorially[†]. The prism having been polished after cementing, so as to ensure the perfect equality of angle of the two parts, on viewing a slit through it the bright line D was seen unbroken in passing from one half to the other. More recently Professor Swan has made a very precise examination of the ordinary refraction in various directions in Iceland spar by the method of prismatic refraction[‡], from whence it results that for homogeneous light of any refrangibility the ordinary ray follows strictly the ordinary law of refraction.

It is remarkable that this simple law, which ought, one would expect, to lie on the very surface as it were of the true theory of double refraction, is not indicated *à priori* by most of the rigorous theories which have been advanced to account for the phenomenon. Neither of the two theories of Cauchy, nor the second theory of Green, lead us to expect such a result, though they furnish arbitrary constants which may be so determined as to bring it about.

The curious and unexpected phenomenon of conical refraction has justly been regarded as one of the most striking proofs of the general correctness of the conclusions resulting from the theory of Fresnel. But I wish to point out that the phenomenon is not competent to decide between several theories leading to Fresnel's construction as a near approximation. Let us take first internal conical refraction. The existence of this phenomenon depends upon the existence of a tangent plane touching the wave surface along a plane curve. At first sight this might seem to be a speciality of the wave-surface of Fresnel; but a little consideration will show that it must be a property of the wave surface resulting from any reasonable theory. For, if possible, let the nearest approach to a plane curve of contact be a curve of double curvature. Let a plane be drawn touching the rim (as it may be called) of the surface, that is, the part where the surface turns over, in two points, on opposite sides of the rim; and then, after having been slightly tilted by turning about one of the points of contact, let it move parallel to itself towards the centre. The successive sections of the wave-surface by this plane will evidently be of the general character represented in the annexed figures,



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[*] Annales de Chimie, tom. xlviii. p. 225 (1831).

[†] Report of the British Association for 1843, Trans. of Sect. p. 7.

[‡] Transactions of the Royal Society of Edinburgh, vol. xvi. p. 375.

and in *four* positions the plane will touch the surface in one point, as represented in figs. 1, 2, 4, 5. Should the contacts represented in figs. 4 & 5 take place simultaneously, they may be rendered successive by slightly altering the inclination of the plane. Hence in certain directions there would be *four* possible wave-velocities. Now the general principle of the superposition of small motions makes the laws of double refraction depend on those of the propagation of plane waves. But all theories respecting the propagation of a series of plane waves having a given direction, and in which the disturbance of the particles is arbitrary, but the same all over the front of a wave, agree in this, that they lead us to decompose the disturbance into three disturbances in three particular directions, to each of which corresponds a series of plane waves which are propagated with a determinate velocity. If the medium be incompressible, one of the wave-velocities becomes infinite, and one sheet of the wave surface moves off to infinity. The most general disturbance, subject to the condition of incompressibility, which requires that there be no displacements perpendicular to the fronts of the waves, may now be expressed as the resultant of *two* disturbances, corresponding to displacements in particular directions lying in planes parallel to that of the waves, to each of which corresponds a determinate velocity of propagation. We see, therefore, that the limitation of the number of tangent planes to the wave-surface, which can be drawn in a given direction on one side of the centre, to two, or at the most three, is intimately bound up with the number of dimensions of space; so that the existence of the phenomenon of internal conical refraction is no proof of the truth of the particular form of wave-surface assigned by Fresnel rather than that to which some other theory would conduct. Were the law of wave-velocity expressed, for example, by the construction already mentioned having reference to the ellipsoid (12), the wave-surface (in this case a surface of the 16th degree) would still have plane curves of contact with the tangent plane, which in this case also, as in the wave-surface of Fresnel, are, as I find, circles, though that they should be circles could not have been foreseen.

The existence of external conical refraction depends upon the existence of a conical point in the wave-surface, by which the interior sheet passes to the exterior. The existence of a conical point is not, like that of a plane curve of contact, a necessary property of a wave-surface. Still it will readily be conceived that if Fresnel's wave-surface be, as it undoubtedly is, at least a near approximation to the true wave-surface, and if the latter have, moreover, plane curves of contact with the tangent plane, the mode by which the exterior sheet passes within one of these plane curves into the interior will be very approximately by a conical point; so that in the impossibility of operating experimentally on mere rays the phenomena will not be sensibly different from what they would have been had the transition been made rigorously by a conical point.

There is one direction within a biaxal crystal marked by a visible phenomenon of such a nature as to permit of observing the direction with precision, while it can also be calculated, on any particular theory of double refraction, in terms of the principal indices of refraction; I refer to the direction of either optic axis. Rudberg himself measured the inclination of the optic axes of Arragonite, probably with a piece of the same crystal from which his prisms were cut, and found it a little more than 32° as observed in air, but he speaks of the difficulty of measuring the angle with precision. The inclination within the crystal thence deduced is really a little greater than that given by Fresnel's theory; but in making the comparison

Rudberg used the formula for the ray-axes instead of that for the wave-axes, which made the theoretical inclination in air appear about 2° greater than the observed[*]. A very exact measure of the angle between the optic axes of Arragonite for homogeneous light corresponding to the principal fixed lines of the spectrum has recently been executed by Professor Kirchhoff[†], by a method which has the advantage of not making any supposition as to the direction in which the crystal is cut. The angle observed in air was reduced by calculation to the angle within the crystal, by means of Rudberg's indices for the principal axis of mean elasticity; and the result was compared with the angle calculated from the formula of Fresnel, on substituting for the constants therein contained the numerical values determined by Rudberg for all the three principal axes. The angle reduced from that observed in air proved to be from 13′ to 20′ greater than that calculated from Fresnel's formula. This small difference seems to be fairly attributable to errors in the indices, arising from errors in the direction of cutting of the prisms employed by Rudberg. The angle measured by Kirchhoff would seem to have been trustworthy to within a minute or less.

It is doubtful, however, how far we may trust to the identity of the principal refractive indices in different specimens of the mineral. Chemical analysis shows that Arragonite is not pure carbonate of lime, but contains a variable though small proportion of other ingredients. To these variations doubtless correspond variations in the refractive indices; and De Senarmont has shown how the inclination of the optic axes of minerals is liable to be changed by the substitution one for another of isomorphous elements[‡]. Moreover, M. Des Cloizeaux has recently shown that in felspar and some other minerals, which bear a high temperature without apparent change, the inclination of the optic axes is changed in a permanent manner by heat[§]; so that even perfect identity of chemical composition is not an absolute guarantee of optical identity in two specimens of a mineral of a given kind.

The exactness of the spheroidal form assigned by Huygens to the sheet of the wave-surface within Iceland spar corresponding to the extraordinary ray, does not seem to have been tested to the same degree of rigour as the ordinary refraction of the ordinary ray; for the methods employed by Wollaston[‖] and Malus[¶] for observing the extraordinary refraction can hardly bear comparison for exactness with the method of prismatic refraction which has been applied to the ordinary ray; and observations on the *absolute* velocities of propagation in different directions within biaxal crystals are still almost wholly wanting. This has long been recognized as a desideratum, and it has been suggested to employ for the purpose the displacement of fringes of interference. It seems to me that a slight modification of the ordinary method of prismatic refraction would be more convenient and exact.

Let the crystal to be examined be cut, unless natural faces or cleavage planes answer the purpose, so as to have two planes inclined at an angle suitable for the measure of refractions; there being at least two natural faces or cleavage-planes left undestroyed, so as to permit of an exact measure of the directions of any artificial faces. The prism thus formed having been mounted as usual, and placed in any azimuth, let the angle of incidence or emergence (according as the prism remains fixed or turns round with the telescope) be measured, by observing the light reflected from the surface, and likewise the deviation for several standard fixed lines in the spectrum of each refracted pencil. Let the prism be now turned into a different azimuth, and the deviations again observed, and so on. Each observation furnishes accurately an angle of incidence and the corresponding angle of emergence; for if ϕ be the angle of incidence, i the angle of the prism, D the deviation, and ψ the angle of emergence, $D=\phi+\psi-i$. But without making any supposition as to the law of double refraction, *or assuming anything beyond the truth of Huygens's principle*, which, following directly from the general principle of the superposition of small motions, lies at the very foundation of the whole theory of undulations, we may at once deduce from the angles of incidence and emergence the direction and velocity of propagation of the wave within the prism. For if a plane wave be incident on a plane surface bounding a medium of any kind, either ordinary or doubly refracting, it follows directly from Huygens's principle that the refracted wave or waves will be plane, and that if ϕ be the angle of incidence, ϕ' the inclination of a refracted wave to the surface, V the velocity of propagation in air, v the wave-velocity within the medium,

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[*] Annales de Chimie, tome xlviii. p. 258 (1831).

[†] Poggendorff's Annalen, vol. cviii. p. 567 (1859).

[‡] Annales de Chimie, tome xxxiii. p. 391 (1851).

[§] Annales des Mines, tome ii. p. 327 (1862).

[‖] On the Oblique Refraction of Iceland Spar, Phil. Trans. for 1802, p. 381.

[¶] Mémoires de l'Institut; Sav. Etrangers, tome ii. p. 303 (1811).

$$\frac{\sin\phi}{V}=\frac{\sin\phi'}{v}.$$

Hence if ϕ', ψ' be the inclinations of the refracted wave to the faces of our prism, we shall have the equations

$$v\sin\phi=V\sin\phi', \quad \dots \quad (13)$$

$$v\sin\psi=V\sin\psi', \quad \dots \quad (14)$$

$$\phi'+\psi'=i. \quad \dots \quad (15)$$

The equations (13) and (14) give, on taking account of (15),

$$v\sin\frac{\phi+\psi}{2}\cos\frac{\phi-\psi}{2}=V\sin\frac{i}{2}\cos\frac{\phi'-\psi'}{2}, \quad \dots \quad (16)$$

$$v\cos\frac{\phi+\psi}{2}\sin\frac{\phi-\psi}{2}=V\cos\frac{i}{2}\sin\frac{\phi'-\psi'}{2}; \quad \dots \quad (17)$$

whence by division

$$\tan\frac{\phi'-\psi'}{2}=\tan\frac{i}{2}\tan\frac{\phi-\psi}{2}\cot\frac{\phi+\psi}{2}. \quad \dots \quad (18)$$

The equations (15) and (18) determine ϕ' and ψ', and then (16) gives v. Hence we know accurately the velocity of propagation of a wave, the normal to which lies in a plane perpendicular to the faces of the prism, and makes known angles with the faces, and is therefore known in direction with reference to the crystallographic axes. A single prism would enable the observer to explore the crystal in a series of directions lying in a plane perpendicular to its edge; but as these directions are practically confined to limits making no very great angles with a normal to the plane bisecting the dihedral angle of the prism, more than one prism would be required to enable him to explore the crystal in the most important directions; and it would be necessary for him to assure himself that the specimens of crystal, of which the different prisms are made, were strictly comparable with each other. It would be best, as far as practicable, to cut them from the same block.

The existence of principal planes, or planes of optical symmetry, for light of any given refrangibility, in those cases in which they are not determined by being at the same time planes of crystallographic symmetry, is a matter needing experimental verification. However, as no anomaly, so far as I am aware, has been discovered in the systems of rings seen with homogeneous light around the optic axes of crystals of the oblique or anorthic system, there is no reason for supposing that such planes do not exist.

APPENDIX.

Further Comparison of the Theories of Green, MacCullagh, *and* Cauchy.

In a paper "On a Classification of Elastic Media and the Laws of Plane Waves propagated through them," read before the Royal Irish Academy on the 8th of January, 1849*, Professor Haughton has made a comparative examination of different theories which have been advanced for determining the motion of elastic media, more especially those which have been applied to the explanation of the phenomena of light. Some of the results contained in this Appendix have already been given by Professor Haughton; in other instances I have arrived at different conclusions. In such cases I have been careful to give my reasons in detail.

Consider a homogeneous elastic medium, the parts of which act on one another only with forces which are insensible at sensible distances, and which in its undisturbed state is either free from pressure, or else subject to a pressure or tension which is the same at all points, though varying with the direction of the plane surface with reference to which it is estimated. Let x, y, z be the coordinates of any particle in the undisturbed state, $x+u$, $y+v$, $z+w$ the coordinates in the disturbed state, and for simplicity take the density in the undisturbed state as the unit of density. Then, according to the method followed both by Green and MacCullagh, the motion of the medium will be determined by the equation

$$\iiint\left(\frac{d^2u}{dt^2}\,\delta u+\frac{d^2v}{dt^2}\,\delta v+\frac{d^2w}{dt^2}\,\delta w\right)dx\,dy\,dz=\iiint\delta\phi\,dx\,dy\,dz, \quad . \quad (19)$$

where ϕ is the function due to the elastic forces. To this equation must be added, in case the medium be not unlimited, the terms relative to its boundaries.

The function ϕ multiplied by $dx\,dy\,dz$ expresses the work given out by the element $dx\,dy\,dz$ in passing from the initial to the actual state if we assume, as we may, the initial state for that in which $\phi=0$. According to the supposition with which we started, that the internal forces are insensible at sensible distances, the value of ϕ at any point must depend on the relative displacements in the immediate neighbourhood of that point, as expressed by the differential coefficients of u, v, w with respect to x, y, z. For the present let us make no other supposition concerning ϕ than this, that it is some function $(-f)$ of those nine differential coefficients; and let us apply the equation (19) to a limited portion of the medium bounded initially by the closed surface S. We must previously add the terms due to the action of the surrounding portion of the medium, which will evidently be of the form of a double integral having reference to the surface S, an element of which we may denote by dS. Hence we must add to the right-hand side of equation (19)

$$\iint \mathrm{E}\,d\mathrm{S},$$

the expression for E having yet to be found.

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* Transactions of the Royal Irish Academy, vol. xxii. p. 97.

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Denoting for shortness the partial differential coefficients of $-\phi$ with respect to $\frac{du}{dx}, \frac{du}{dy}$, &c. by $f\left(\frac{du}{dx}\right), f\left(\frac{du}{dy}\right)$, &c., we have

$$-\delta\phi = f\left(\frac{du}{dx}\right)\delta\frac{du}{dx} + f\left(\frac{du}{dy}\right)\delta\frac{du}{dy} + \&c.$$
$$= f\left(\frac{du}{dx}\right)\frac{d\delta u}{dx} + f\left(\frac{du}{dy}\right)\frac{d\delta u}{dy} + \&c.,$$

whence

$$-\iiint\delta\phi\, dx\, dy\, dz = \iiint f\left(\frac{du}{dx}\right)\frac{d\delta u}{dx}\, dx\, dy\, dz + \iiint f\left(\frac{du}{dy}\right)\frac{d\delta u}{dy}\, dx\, dy\, dz + \&c.$$
$$= \iint f\left(\frac{du}{dx}\right)\delta u\, dy\, dz + \iint f\left(\frac{du}{dy}\right)\delta u\, dz\, dx + \iint f\left(\frac{du}{dz}\right)\delta u\, dx\, dy$$
$$+ \iint f\left(\frac{dv}{dx}\right)\delta v\, dy\, dz + \&c.$$
$$-\iiint\left\{\delta u\frac{d}{dx}f\left(\frac{du}{dx}\right) + \delta u\frac{d}{dy}f\left(\frac{du}{dy}\right) + \delta u\frac{d}{dz}f\left(\frac{du}{dz}\right) + \delta v\frac{d}{dx}f\left(\frac{dv}{dx}\right)\right.$$
$$\left. + \&c.\right\} dx\, dy\, dz.$$

We must now equate to zero separately the terms in our equation involving triple and those involving double integrals. The result obtained from the former further requires that the coefficient of each of the independent quantities $\delta u, \delta v, \delta w$ under the sign $\iiint$ shall vanish separately, whence

$$\left.\begin{aligned}\frac{d^2u}{dt^2} &= \frac{d}{dx}f\left(\frac{du}{dx}\right) + \frac{d}{dy}f\left(\frac{du}{dy}\right) + \frac{d}{dz}f\left(\frac{du}{dz}\right),\\ \frac{d^2v}{dt^2} &= \frac{d}{dx}f\left(\frac{dv}{dx}\right) + \frac{d}{dy}f\left(\frac{dv}{dy}\right) + \frac{d}{dz}f\left(\frac{dv}{dz}\right),\\ \frac{d^2w}{dt^2} &= \frac{d}{dx}f\left(\frac{dw}{dx}\right) + \frac{d}{dy}f\left(\frac{dw}{dy}\right) + \frac{d}{dz}f\left(\frac{dw}{dz}\right),\end{aligned}\right\} \quad . \quad . \quad . \quad (20)^*$$

equations which may be written in an abbreviated form as follows:—

$$\frac{d^2u}{dt^3} = -\left[\frac{d\phi}{du}\right],\quad \frac{d^2v}{dt^2} = -\left[\frac{d\phi}{dv}\right],\quad \frac{d^2w}{dt^2} = -\left[\frac{d\phi}{dw}\right], \quad . \quad . \quad (21)$$

where the expressions within crotchets denote differential coefficients taken in a conventional sense, namely by treating in the differentiation the symbols $\frac{d}{dx}, \frac{d}{dy}, \frac{d}{dz}$ as if they were mere literal coefficients, and prefixing to the whole term, and now regarding as a real symbol of differentiation, whichever of these three symbols was attached to the u, v, or w that disappeared by differentiation.

The equating of the double integrals gives

$$\iint \mathrm{E}\, d\mathrm{S} = \iint f\left(\frac{du}{dx}\right)\delta u\, dy\, dz + \iint f\left(\frac{du}{dy}\right)\delta u\, dz\, dx + \&c.$$
$$= \iint\left\{\left[lf\left(\frac{du}{dx}\right) + mf\left(\frac{du}{dy}\right) + nf\left(\frac{du}{dz}\right)\right]\delta u + [\&c.]\,\delta v + [\&c.]\,\delta w\right\} d\mathrm{S},$$

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* These agree with Professor Haughton's equations (5).

where l, m, n are the direction-cosines of the element $d\mathrm{S}$ of the surface which bounded the portion of the medium under consideration when it was in its undisturbed state. This expression leads us to contemplate the action of the surrounding medium as a tension having a certain value referred to a unit of surface in the undisturbed state. If P, Q, R be the components of this tension parallel to the axes of x, y, z, they must be the coefficients of $\delta u, \delta v, \delta w$ under the sign $\iint$, so that

$$\left.\begin{aligned}\mathrm{P}&=lf'\left(\frac{du}{dx}\right)+mf'\left(\frac{du}{dy}\right)+nf'\left(\frac{du}{dz}\right),\\ \mathrm{Q}&=lf'\left(\frac{dv}{dx}\right)+mf'\left(\frac{dv}{dy}\right)+nf'\left(\frac{dv}{dz}\right),\\ \mathrm{R}&=lf'\left(\frac{dw}{dx}\right)+mf'\left(\frac{dw}{dy}\right)+nf'\left(\frac{dw}{dz}\right).\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (22)$$

These formulæ give, in terms of the function ϕ, the components of the tension on a small plane which in its original position had any arbitrary direction. If we wish for the expressions for the components of the tensions on planes originally perpendicular to the axes of x, y, z, we have only to put in succession $l=1$, $m=1$, $n=1$, the other two cosines each time being equal to zero. If then P_x, T_{yx}, T_{zx} denote the components in the direction of the axis of x of the tension on planes originally perpendicular to the axes of x, y, z, with similar notation in the other cases, we shall have

$$\left.\begin{aligned}\mathrm{P}_x&=f'\left(\frac{du}{dx}\right), & \mathrm{T}_{yz}&=f'\left(\frac{dw}{dy}\right), & \mathrm{T}_{zy}&=f'\left(\frac{dv}{dz}\right),\\ \mathrm{P}_y&=f'\left(\frac{dv}{dy}\right), & \mathrm{T}_{zx}&=f'\left(\frac{du}{dz}\right), & \mathrm{T}_{xz}&=f'\left(\frac{dw}{dx}\right),\\ \mathrm{P}_z&=f'\left(\frac{dw}{dz}\right), & \mathrm{T}_{xy}&=f'\left(\frac{dv}{dx}\right), & \mathrm{T}_{yx}&=f'\left(\frac{du}{dy}\right).\end{aligned}\right\} \quad . \quad . \quad (23)^*$$

The formulæ hitherto employed are just the same whether we suppose the disturbance small or not; and we might express in terms of P_x, T_{yz}, &c. (and therefore in terms of ϕ), and of the differential coefficients of u, v, w with respect to x, y, and z, the components of the tension referred to a surface given in the actual instead of the undisturbed state of the medium, without supposing the disturbance small. As, however, the investigation is meant to be applied only to small disturbances, it would only complicate the formulæ to no purpose to treat the disturbance as of arbitrary magnitude, and I shall therefore regard it henceforth as indefinitely small.

On this supposition we may expand ϕ according to powers of the small quantities $\frac{du}{dx}$, &c., proceeding as far as the second order, the left-hand member of (19) being of the second order as regards u, v, w. The formulæ (22) or (23) show that ϕ will or will not contain terms of the first order according as the undisturbed state of the medium is one of uniform constraint, or of freedom from pressure.

In Green's first theory, and in the theory of MacCullagh, ϕ is supposed not to contain terms of the first order. Accordingly in considering the point with respect to which these two theories are at issue, I shall suppose the medium in its undisturbed state to be free from pressure. The tensions P, Q, R, P_x, &c. will now be small quantities of the first order, so that in the formulæ (22) and (23) we may suppose the tensions referred to a unit of surface in the actual or the undisturbed state of the medium indifferently, and may moreover in these formulæ, and in the expression for ϕ, take x, y, z for the actual or the original coordinates of a particle.

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* These agree with Professor Haughton's equations at p. 100, but are obtained in a different manner.

Green assumes as self-evident that the value of ϕ for any element, suppose that which originally occupied the rectangular parallelepiped $dx\,dy\,dz$, must depend only on the change of form of the element, and not on any mere change of position in space. Any displacement which varies continuously from point to point must change an elementary rectangular parallelepiped into one which is oblique-angled, and the change of form is expressed by the ratios of the lengths of the edges to the original lengths, and by the angles which the edges make with one another or by their cosines. If the medium were originally in a state of constraint, ϕ would contain terms of the first order, and the expressions for the extensions of the edges and the cosines of the angles would be wanted to the second order, but when ϕ is wholly of the second order, those quantities need only be found to the first order. It is easy to see that to this order the extensions are expressed by

$$\frac{du}{dx}, \qquad \frac{dv}{dy}, \qquad \frac{dw}{dz}, \quad \ldots \ldots \ldots \quad (24)$$

and the cosines of the inclinations of the edges two and two by

$$\frac{dv}{dz}+\frac{dw}{dy}, \qquad \frac{dw}{dx}+\frac{du}{dz}, \qquad \frac{du}{dy}+\frac{dv}{dx}, \quad \ldots \ldots \quad (25)$$

and ϕ being a function of these six quantities, we have from (23)

$$T_{yz}=T_{zy}, \qquad T_{zx}=T_{xz}, \qquad T_{xy}=T_{yx}. \quad \ldots \ldots \quad (26)$$

These are the relations pointed out by Cauchy between the nine components of the three tensions in three rectangular directions, whereby they are reduced to six. The necessity of these relations is admitted by most mathematicians.

Conversely, if we start with Cauchy's three relations (26), we have from (23)

$$f'\left(\frac{dw}{dy}\right)=f'\left(\frac{dv}{dz}\right), \qquad f'\left(\frac{du}{dz}\right)=f'\left(\frac{dw}{dx}\right), \qquad f'\left(\frac{dv}{dx}\right)=f'\left(\frac{du}{dy}\right). \quad (27)$$

The integration of the first of these partial differential equations gives

$$f=\text{a function of } \frac{dw}{dy}+\frac{dv}{dz} \text{ and of the seven other differential coefficients.}$$

Substituting in the second of equations (27) and integrating, and substituting the result in the third and integrating again, we readily find

$$f=\text{a function of the six quantities (24) and (25).}$$

We see then that Green's axiom that the function ϕ depends only on the change of form of the element, and Cauchy's relations (26), are but different ways of expressing the same condition; so that either follows if the truth of the other be admitted.

Cauchy's equations were proved by applying the statical equations of moments of a rigid body to an elementary parallelepiped of the medium, and taking the limit when the dimensions of the element vanish. The demonstration is just the same whether the medium be at rest or in motion, since in the latter case we have merely to apply d'Alembert's principle. It need hardly be remarked that the employment of equations of equilibrium of a rigid body in the demonstration by no means limits the truth of the theorem to rigid bodies; for the equations of equilibrium of a rigid body are true of any material system. In the latter case they are not *sufficient* for the equilibrium, but all that we are concerned with in the demonstration of equations (26) is that they should be *true*.

On the other hand, the form of V or ϕ to which MacCullagh was led is that of a homogeneous function, of the second order, of the three quantities

$$\frac{dw}{dy}-\frac{dv}{dz},\quad \frac{du}{dz}-\frac{dw}{dx},\quad \frac{dv}{dx}-\frac{du}{dy}, \quad . \quad . \quad . \quad . \quad , \qquad (28)$$

which, as is well known, are linear functions of the similarly expressed quantities referring to any other system of rectangular axes. On substituting in (23), we see that the normal tensions on planes parallel to the coordinate planes, and therefore on any plane since the axes are arbitrary, vanish, while the tangential tensions satisfy the three relations

$$T_{yz}=-T_{zy},\quad T_{zx}=-T_{xz},\quad T_{xy}=-T_{yx}; \quad . \quad . \quad . \qquad (29)$$

so that the equations of moments of an element are violated. The relative motion in the neighbourhood of a given point may be resolved, as is known, into three extensions (positive or negative) in three rectangular directions and three rotations. The directions of the axes of extension, and the magnitudes of the extensions, are determined by the six quantities (24) and (25), while the rotations or angular displacements are expressed by the halves of the three quantities (28). In this theory, then, the work stored up in an element of the medium would depend, not upon the change of form of the element, but upon its angular displacement in space.

It may be shown without difficulty that, according to the form of ϕ assumed by MacCullagh, the equations of moments are violated for a finite portion of the mass, and not merely for an element. Supposing for simplicity that the medium in its undisturbed state is free from pressure or tension, let us leave the form of ϕ open for the present, except that it is supposed to be a function of the differential coefficients of the first order of u, v, w with respect to x, y, z, and let us form the equation of moments round one of the axes, as that of x, for the portion of the medium comprised within the closed surface S. This equation is

$$\iiint\left\{-\frac{d^2w}{dt^2}y+\frac{d^2v}{dt^2}z\right\}dx\,dy\,dz+\iint(\mathrm{R}y-\mathrm{Q}z)\,d\mathrm{S}=0,$$

the double integrals belonging to the surface. Since all the terms in this equation are small, we may take x, y, z for the actual or the equilibrium coordinates indifferently. Substituting from equations (20), and integrating by parts, we find

$$\iint\left\{f'\left(\frac{dv}{dx}\right)z-f'\left(\frac{dw}{dx}\right)y\right\}dy\,dz+\iint\left\{f'\left(\frac{dv}{dy}\right)z-f'\left(\frac{dw}{dy}\right)y\right\}dz\,dx$$
$$+\iint\left\{f'\left(\frac{dv}{dz}\right)z-f'\left(\frac{dw}{dz}\right)y\right\}dx\,dy+\iint(\mathrm{R}y-\mathrm{Q}z)\,d\mathrm{S}$$
$$+\iiint\left\{f'\left(\frac{dw}{dy}\right)-f'\left(\frac{dv}{dz}\right)\right\}dx\,dy\,dz=0.$$

The double integrals in this equation destroy each other by virtue of (22), so that there remains

$$\iiint\left\{f'\left(\frac{dw}{dy}\right)-f'\left(\frac{dv}{dz}\right)\right\}dx\,dy\,dz=0. \quad . \quad . \quad . \quad . \qquad (30)$$

But this equation cannot be satisfied, since the surface S within which the integration is to be performed is perfectly arbitrary, unless $f\left(\frac{dw}{dy}\right)=f\left(\frac{dv}{dz}\right)$ at all points. We are thus led back to the equations (27), which are violated in the theory of MacCullagh.

The form of the equations such as (30) is instructive, as pointing out the mode in which the condition of moments is violated. It is not that the resultant of the forces acting on an element of the medium does not produce its proper momentum in changing the motion of translation of the element; that is secured by the equations (20); but that a couple is supposed to act on each element to which there is no corresponding reacting couple.

The only way of escaping from these conclusions is by denying that the mutual action of two adjacent portions of the medium separated by a small ideal surface is capable of being represented by a pressure or tension, and saying that we must also take into account a couple; not, it is to be observed, a couple depending on variations of the tension (for that would be of a higher order and would vanish in the limit), but a couple ultimately proportional to the element of surface. But it would require a function ϕ of a totally different form to take into account the work of such couples; and indeed the method by which the expressions for the components of the tension have been here deduced seems to show that in the case of a function ϕ which depends only on the differential coefficients of the first order of u, v, w with respect to x, y, z, the mutual action of two contiguous portions of a medium *is* fully represented by a tension or pressure.

Indeed MacCullagh himself expressly disclaimed having given a mechanical theory of double refraction*. His methods have been characterized as a sort of mathematical induction, and led him to the discovery of the mathematical laws of certain highly important optical phenomena. The discovery of such laws can hardly fail to be a great assistance towards the future establishment of a complete mechanical theory.

I proceed now to form the function ϕ for Cauchy's most general equations. If we have given the expressions for $\frac{d^2u}{dt^2}, \frac{d^2v}{dt^2}, \frac{d^2w}{dt^2}$ in terms of the differential coefficients of u, v, w with respect to x, y, z, they do not suffice for the complete determination of the function ϕ, as appears from the equations (20) or (21); but if we have given the expressions for the tensions P_x, T_{yz}, &c., ϕ is completely determinate, as appears from equations (23). In using these equations, it must be remembered that the tensions are measured with reference to surfaces in the undisturbed state of the medium; and therefore, should the expressions be given with reference to surfaces in the actual state, they must undergo a preliminary transformation to make them refer to surfaces in the undisturbed state.

Supposing then the tensions expressed as required, in order to find ϕ we have only to integrate the total differential

$$-d\phi=P_x\,d\frac{du}{dx}+P_y\,d\frac{dv}{dy}+P_z\,d\frac{dw}{dz}+T_{yz}\,d\frac{dw}{dy}+T_{zx}\,d\frac{du}{dz}+T_{xy}\,d\frac{dv}{dx}$$
$$+T_{zy}\,d\frac{dv}{dz}+T_{xz}\,d\frac{dw}{dx}+T_{yx}\,d\frac{du}{dy}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (31)$$

the nine differential coefficients, of which ϕ is a function, being regarded as independent variables. Should the three equations (27) be satisfied, the expression (31) will be simplified, becoming

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* Transactions of the Royal Irish Academy, vol. xxi. p. 50. It would seem, however, that he rather felt the want of a mechanical theory from which to deduce his form of the function ϕ or V, than doubted the correctness of that form itself.

$$-d\phi=\mathrm{P}_x\,d\frac{du}{dx}+\mathrm{P}_y\,d\frac{dv}{dy}+\mathrm{P}_z\,d\frac{dw}{dz}+\mathrm{T}_x\,d\left(\frac{dw}{dy}+\frac{dv}{dz}\right)+\mathrm{T}_y\,d\left(\frac{du}{dz}+\frac{dw}{dx}\right)$$
$$+\mathrm{T}_z\left(\frac{dv}{dx}+\frac{du}{dy}\right), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (32)$$

where T_x denotes T_{yz} or T_{zy}, and similarly for T_y, T_z.

The general expressions for the tensions resulting from Cauchy's method are written at length in the equations numbered 17 and 18, pp. 133, 134 of the 4th volume of his 'Exercices de Mathématiques,' where the normal and tangential tensions, referred to surfaces in the actual state of the medium, are denoted by A, B, C, D, E, F. These expressions contain 21 arbitrary constants, of which six, $\mathfrak{A}$, $\mathfrak{B}$, $\mathfrak{C}$, $\mathfrak{D}$, $\mathfrak{E}$, $\mathfrak{F}$, denote the tensions in the state of equilibrium. If these be for the present omitted, the remaining terms will be wholly small quantities of the first order, and therefore the tensions may be supposed to be referred to a unit of surface in the actual, or in the undisturbed state of the medium indifferently. On substituting now for P_x, P_y, P_z, T_x, T_y, T_z in (32) the remaining parts of A, B, C, D, E, F (observing that the ξ, η, ζ in Cauchy's notation are the same as u, v, w), it will be seen that the right-hand member of the equation is a perfect differential, integrable at once by inspection, and giving

$$\left.\begin{aligned}
-2\phi=&\,\mathrm{L}\left(\frac{du}{dx}\right)^2+\mathrm{M}\left(\frac{dv}{dy}\right)^2+\mathrm{N}\left(\frac{dw}{dz}\right)^2+\mathrm{P}\left\{\left(\frac{dv}{dz}+\frac{dw}{dy}\right)^2+2\frac{dv}{dy}\frac{dw}{dz}\right\}\\
&+\mathrm{Q}\left\{\left(\frac{dw}{dx}+\frac{du}{dz}\right)^2+2\frac{dw}{dz}\frac{du}{dx}\right\}+\mathrm{R}\left\{\left(\frac{du}{dy}+\frac{dv}{dx}\right)^2+2\frac{du}{dx}\frac{dv}{dy}\right\}\\
&+2\mathrm{U}\left\{\frac{du}{dx}\left(\frac{dv}{dz}+\frac{dw}{dy}\right)+\left(\frac{dw}{dx}+\frac{du}{dz}\right)\left(\frac{du}{dy}+\frac{dv}{dx}\right)\right\}\\
&+2\mathrm{V}'\left\{\frac{dv}{dy}\left(\frac{dw}{dx}+\frac{du}{dz}\right)+\left(\frac{du}{dy}+\frac{dv}{dx}\right)\left(\frac{dv}{dz}+\frac{dw}{dy}\right)\right\}\\
&+2\mathrm{W}''\left\{\frac{dw}{dz}\left(\frac{du}{dy}+\frac{dv}{dx}\right)+\left(\frac{dv}{dz}+\frac{dw}{dy}\right)\left(\frac{dw}{dx}+\frac{du}{dz}\right)\right\}\\
&+2\mathrm{V}\frac{du}{dx}\left(\frac{dw}{dx}+\frac{du}{dz}\right)+2\mathrm{W}'\frac{dv}{dy}\left(\frac{du}{dy}+\frac{dv}{dx}\right)+2\mathrm{U}''\frac{dw}{dz}\left(\frac{dv}{dz}+\frac{dw}{dy}\right)\\
&+2\mathrm{W}\frac{du}{dx}\left(\frac{du}{dy}+\frac{dv}{dx}\right)+2\mathrm{U}'\frac{dv}{dy}\left(\frac{dv}{dz}+\frac{dw}{dy}\right)+2\mathrm{V}''\frac{dw}{dz}\left(\frac{dw}{dx}+\frac{du}{dz}\right),
\end{aligned}\right\}\quad(33)$$

the arbitrary constant being omitted as unnecessary. We see that this is a homogeneous function of the second degree of the six quantities (24) and (25), but not the most general function of that nature, containing only 15 instead of 21 arbitrary constants.

Let us now form the part of the expression for ϕ involving the constants which express the pressures in the state of equilibrium. It will be convenient to effect the requisite transformation in the expressions for the tensions by two steps, first referring them to surfaces of the actual extent, but in the original position, and then to surfaces in the original state altogether.

Let P'_x, T'_{yz}, &c. denote the tensions estimated with reference to the actual extent but original direction of a surface, so that $\mathrm{P}'_x\,d\mathrm{S}$, for instance, denotes the component, in a direction parallel to the axis of x, of the tension on an elementary plane passing through the point (x, y, z) in such a direction that in the undisturbed state of the medium the same plane of particles was perpendicular to the axis of x, dS denoting the actual area of the element. Consider the equilibrium of an elementary tetrahedron of the medium, the sides of which are perpendicular to the axes of x, y, z, and the base in the direction of a plane which was perpendicular to the axis of x; and let l, m, n be the direction-cosines of the base; then

$$P'_x = lA + mF + nE, \quad T'_{xy} = lF + mB + nD, \quad T'_{xz} = lE + mD + nC; \qquad (34)$$

but to the first order of small quantities

$$l = 1, \quad m = -\frac{du}{dy}, \quad n = -\frac{du}{dz};$$

substituting in (34), and writing down the other corresponding equations, we have

$$\left.\begin{array}{l|l|l}
P'_x = A - F\dfrac{du}{dy} - E\dfrac{du}{dz} & T'_{yz} = D - C\dfrac{dv}{dz} - E\dfrac{dv}{dx} & T'_{zy} = D - F\dfrac{dw}{dx} - B\dfrac{dw}{dy} \\
P'_y = B - D\dfrac{dv}{dz} - F\dfrac{dv}{dx} & T'_{zx} = E - A\dfrac{dw}{dx} - F\dfrac{dw}{dy} & T'_{xz} = E - D\dfrac{du}{dy} - C\dfrac{du}{dz} \\
P'_z = C - E\dfrac{dw}{dx} - D\dfrac{dw}{dy} & T'_{xy} = F - B\dfrac{du}{dy} - D\dfrac{du}{dz} & T'_{yx} = F - E\dfrac{dv}{dz} - A\dfrac{dv}{dx}
\end{array}\right\} (35)$$

Lastly, since an elementary area dS originally perpendicular to the axis of x becomes by extension $\left(1+\frac{dv}{dy}+\frac{dw}{dz}\right) dS$, and similarly with regard to y and z, we have

$$\left.\begin{array}{l}
P_x : P'_x = T_{xy} : T'_{xy} = T_{xz} : T'_{xz} = 1 + \dfrac{dv}{dy} + \dfrac{dw}{dz}, \\
P_y : P'_y = T_{yz} : T'_{yz} = T_{yx} : T'_{yx} = 1 + \dfrac{dw}{dz} + \dfrac{du}{dx}, \\
P_z : P'_z = T_{zx} : T'_{zx} = T_{zy} : T'_{zy} = 1 + \dfrac{du}{dx} + \dfrac{dv}{dy}.
\end{array}\right\} \quad . \; . \; . \quad (36)$$

Expressing P_x, T_{xy}, &c. in terms of P'_x, T'_{xy}, &c. by (36), then P'_x, T'_{xy}, &c. in terms of A, B, C, D, E, F by (35), and lastly substituting for A, B . . . F the expressions given by Cauchy, we find

$$\left.\begin{array}{l|l}
\multicolumn{2}{c}{P_x = \mathfrak{A}\left(1+\dfrac{du}{dx}\right) + \mathfrak{F}\dfrac{du}{dy} + \mathfrak{E}\dfrac{du}{dz}} \\
\multicolumn{2}{c}{P_y = \mathfrak{B}\left(1+\dfrac{dv}{dy}\right) + \mathfrak{D}\dfrac{dv}{dz} + \mathfrak{F}\dfrac{dv}{dx}} \\
\multicolumn{2}{c}{P_z = \mathfrak{C}\left(1+\dfrac{dw}{dz}\right) + \mathfrak{E}\dfrac{dw}{dx} + \mathfrak{D}\dfrac{dw}{dy}} \\
T_{yz} = \mathfrak{D}\left(1+\dfrac{dw}{dz}\right) + \mathfrak{F}\dfrac{dw}{dx} + \mathfrak{B}\dfrac{dw}{dy} & T_{zy} = \mathfrak{D}\left(1+\dfrac{dv}{dy}\right) + \mathfrak{E}\dfrac{dv}{dx} + \mathfrak{C}\dfrac{dv}{dz} \\
T_{zx} = \mathfrak{E}\left(1+\dfrac{du}{dx}\right) + \mathfrak{D}\dfrac{du}{dy} + \mathfrak{C}\dfrac{du}{dz} & T_{xz} = \mathfrak{E}\left(1+\dfrac{dw}{dz}\right) + \mathfrak{F}\dfrac{dw}{dy} + \mathfrak{A}\dfrac{dw}{dx} \\
T_{xy} = \mathfrak{F}\left(1+\dfrac{dv}{dy}\right) + \mathfrak{E}\dfrac{dv}{dz} + \mathfrak{A}\dfrac{dv}{dx} & T_{yx} = \mathfrak{F}\left(1+\dfrac{du}{dx}\right) + \mathfrak{D}\dfrac{du}{dz} + \mathfrak{B}\dfrac{du}{dy}
\end{array}\right\} (37)$$

Substituting now these expressions in (31) and integrating, we have

$$\left.\begin{aligned}-2\phi=\mathfrak{A}&\left\{2\frac{du}{dx}+\left(\frac{du}{dx}\right)^2+\left(\frac{dv}{dx}\right)^2+\left(\frac{dw}{dx}\right)^2\right\}\\
+\mathfrak{B}&\left\{2\frac{dv}{dy}+\left(\frac{du}{dy}\right)^2+\left(\frac{dv}{dy}\right)^2+\left(\frac{dw}{dy}\right)^2\right\}\\
+\mathfrak{C}&\left\{2\frac{dw}{dx}+\left(\frac{du}{dz}\right)^2+\left(\frac{dv}{dz}\right)^2+\left(\frac{dw}{dz}\right)^2\right\}\\
+2\mathfrak{D}&\left\{\frac{dv}{dz}+\frac{dw}{dy}+\frac{du}{dy}\frac{du}{dz}+\frac{dv}{dy}\frac{dv}{dz}+\frac{dw}{dy}\frac{dw}{dz}\right\}\\
+2\mathfrak{E}&\left\{\frac{dw}{dx}+\frac{du}{dz}+\frac{du}{dz}\frac{du}{dx}+\frac{dv}{dz}\frac{dv}{dx}+\frac{dw}{dz}\frac{dw}{dx}\right\}\\
+2\mathfrak{F}&\left\{\frac{du}{dy}+\frac{dv}{dx}+\frac{du}{dx}\frac{du}{dy}+\frac{dv}{dx}\frac{dv}{dy}+\frac{dw}{dx}\frac{dw}{dy}\right\},\end{aligned}\right\}\quad\ldots\quad(38)$$

which is exactly Green's expression*, Green's constants A, B . . . F answering to Cauchy's $\mathfrak{A}$, $\mathfrak{B}$ . . . $\mathfrak{F}$. The sum of the right-hand members of equations (33) and (38) gives the complete expression for -2ϕ which belongs to Cauchy's formulæ. It contains, as we see, 21 arbitrary constants, and is a particular case of the general form used by Green, which latter contains 27 arbitrary constants.

I have been thus particular in deducing the form of Green's function which belongs to Cauchy's expressions, partly because it has been erroneously asserted that Green's function does not apply to a system of attracting and repelling molecules, partly because, when once the function ϕ is formed, the short and elegant methods of Green may be applied to obtain the results of Cauchy's theory, and a comparison of the different theories of Green and Cauchy is greatly facilitated.

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* Cambridge Philosophical Transactions, vol. vii. p. 127.

Fourth Report of the Committee on Steamship Performance.

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REPORT.

["The object of the Committee is to make public such recorded facts through the medium of the Association, and being accessible to the public in that manner, to bring the greatest amount of science to the solution of the difficulties now existing to the scientific improvement of the forms of vessels and the qualities of marine engines. They will especially endeavour to guard against information so furnished to them being used in any other way, and they trust they may look for the cooperation of members of Yacht Clubs having steam-yachts, of shipowners, as well as of steamship-builders and engineers."—*Third Report*, 1861, p. 16.]

At the meeting of the British Association held at Manchester in September 1861, the Committee were reappointed in the following terms:—

"That the Committee on Steamship Performance be reappointed.

"That the attention of the Committee be also directed to the obtaining of information regarding the performance of vessels under sail, with a view to comparing the result of the two powers of wind and steam, in order to their more effectual and economical combination; with £150 at their disposal."

The following noblemen and gentlemen were nominated to serve on the Committee:—

The Duke of Sutherland.
The Earl of Gifford, M.P.
The Earl of Caithness.
The Lord Dufferin.
W. Fairbairn, Esq., LL.D., F.R.S.
J. Scott Russell, Esq., F.R.S.
Admiral E. Paris, C.B. (Imperial French Navy).
The Hon. Capt. Egerton, R.N.
The Hon. Leopold Agar Ellis, M.P.
J. E. McConnell, Esq., C.E.
Wm. Smith, Esq., C.E.
Prof. J. M. Rankine, LL.D.
J. R. Napier, Esq.
R. Roberts, Esq., C.E.
Henry Wright, Esq., Secretary.

With power to add to their number.

The following noblemen and gentlemen, having consented to assist your Committee, were, during the present year, elected as corresponding members:—

Lord C. Paget, M.P., C.B.
The Earl of Durham.
The Marquis of Hartington, M.P.
Viscount Hill.
Lord John Hay.
Admiral Elliott.
Captain Hope, R.N.
Captain Ryder, R.N.
Robert Dalglish, Esq., M.P.
Captain Robertson, R.N.
Captain Sulivan, R.N., C.B.
Captain Mangles.
T. R. Tufnell, Esq.
Wm. Froude, Esq.
W. Just, Esq.
John Elder, Esq.
David Rowan, Esq.
J. Mc F. Gray, Esq.

Your Committee have the pleasure of stating that, at the unanimous request of the members of the Committee, his Grace the Duke of Sutherland undertook the office of Chairman. The Committee have, since February last, held monthly meetings, and intermediate meetings of a sub-Committee.

Your Committee have pleasure in reporting very satisfactory progress, and that they have had an increasing amount of useful information placed at their disposal. Much greater interest is now taken in the objects of the inquiry, and a still increasing number of observers have adopted the forms of the Committee, for recording the performances of vessels.

The importance of the information collected by your Committee is attracting the attention of steamship-owners, as well as scientific investigators; and it is hoped the result of greater efficiency and economy in the application of steam, as well as improvements in the construction of steam-vessels, will be the result of these Reports; and your Committee have reason to believe that considerable advantages have already been derived from their labours by steamship-owners.

The Royal Navy.—Your Committee, in their Third Annual Report, stated the results of their communications with the Admiralty, and have now to report that the objects of your Committee continue to meet with the approval of the Lords Commissioners of the Admiralty, and of the intelligent scientific officers in that branch of Her Majesty's service; that your Committee have been furnished from time to time with accurate returns of the performances of the more important steamships in Her Majesty's service which have been tried at the measured mile during the last twelve months, and also some similar returns, received too late for insertion in the Report of last year. In the Appendix will be found a selection from these returns, preference having been given to the returns of vessels of which the future steam performances at sea have been promised.

Your Committee have received several returns of performances of Her Majesty's ships at sea, the publication of which, owing to their being incomplete in some important particulars, and to the lateness of the time at which they were received, is necessarily postponed.

Your Committee call attention to the selection they have made, which will be found in the Appendix.

As numerous inquiries have, from time to time, been made of your Committee as to the particulars of certain of Her Majesty's steamships, the performances of which were noticed in previous Reports, your Committee, with a view to avoid unnecessary correspondence, and to give the required information more fully than can be done by written communications, determined to include in the present Report three sets of tables of trials of H.M.'s ships, which were officially tabulated by the Admiralty, but not issued by them to the public.

The reprinting of those tables, and the textual information accompanying them, in the Appendix to the present Report will now supply those who possess the previous Reports of your Committee with the means of comparing the results obtained upon the trials of nearly the entire of the steamships of war composing the British Navy, and will also enable them to compare with the results of such trials the performances whilst at sea of very many of the vessels included in the complete and extensive lists to be found in the three Reports previously published, and in the present Report of your Committee, without the necessity, which before existed, of searching elsewhere for the information.

The publication of the three Admiralty Tables will also render it unnecessary hereafter to repeat many particulars as to the dimensions, &c., of the ships, and the power and other details of the engines of such of H.M.'s ships of which your Committee may, from time to time, receive returns of performances at sea.

In the previous Reports, the records of special trials with propellers of various kinds, in the steamships 'Flying Fish,' 'Bullfinch,' 'Doris,' &c., were given; and the Committee are now enabled to furnish another series of experiments with Her Majesty's gunboat 'Stork,' which are very interesting, and to which is added a short abstract of the trials of the 'Shannon' and 'Psyche.'

The Steam Transport Service.—A series of tables, prepared by Mr. G. Murdoch, Superintending Engineer at Constantinople during the Crimean War, and now Inspecting Engineer of Her Majesty's Steam Reserve at Portsmouth, having been carefully calculated for the purpose of showing the respective values of the several steamships, classified according to the nature of the employment or the special character of the duties required to be performed, have been placed at the disposal of your Committee. These tables, besides giving the expense of moving each ship 1000 miles, and the cost of conveying sick and wounded officers and troops, cavalry, cattle, and cargo, over the same distance, give the daily coal-consumption and the distance run for each ton of coal consumed. They have also the additional value arising from contrasting the different results obtained, and costs incurred, when propelling the same vessels at different speeds.

Royal Mail Service.—Your Committee have been favoured with a copy of the Engine Register kept by the West India Royal Mail Steam Packet Company, showing the exact performances of some of their largest steamships. The tabulated statement, which will be found appended to this Report, is for the twelve months ending June last, and has reference only to the steamers employed on the West India Transatlantic route between Southampton and St. Thomas.

To this Form of Return your Committee would invite special attention, as they are not aware that such is kept by any of the other large Steam Packet Companies or steamship-owners; and the great value of the information it affords, as also the very complete form in which that information is rendered, will, it is thought, be admitted by every one who is conversant with such matters. The importance of such a record to a corporation like the Royal Mail Company can hardly be over-estimated, when it is considered that they have no less than nine distinct routes of steamers in the West Indies and the Brazils, and that exactly the same system is adopted in regard to all these; so that the performance of every vessel engaged on these lines is, on the completion of each succeeding voyage, thus carefully analysed and brought under the immediate notice of the managers.

In addition to the above, indicator diagrams are taken from the engines on every voyage, and sent home for inspection; the particulars of these are further entered in a register kept for that purpose. The Royal Mail Company have kindly furnished your Committee with a copy of their register of the diagrams taken on all the voyages comprised in the first-mentioned table, thus affording a complete synopsis of the working both of their ships and engines on the West India Transatlantic route, during the twelve months referred to.

Your Committee have included also the dimensions and other particulars of the 'Mooltan,' a new vessel belonging to the Peninsular and Oriental Steam Navigation Company, with returns of a voyage from Southampton to Alexandria and back, showing the results of the performance of this vessel, as compared with some other vessels in the same service. It is to be regretted that the Peninsular and Oriental Company found they were unable to give a continuance of the reports of the performances of the vessels composing their fleet of ships this year in time for the publication of this Report. The Committee have reason to believe that next year full reports of the performances of these vessels for this and next year will be forthcoming.

The Pacific Royal Mail Company have furnished your Committee with the dimensions and abstract of the performances of their last additions to their fleet (see Appendix). The particulars of the other vessels have been given in previous Reports.

It is worthy of remark that the vessels belonging to this Company fitted with double-cylinder expansion engines, specially noticed by your Committee in previous Reports as remarkable for their economy, have continued to perform in the same economical manner; and, under the circumstances, it has not been considered necessary to furnish a continuation of the logs previously given.

The City of Dublin Company's Returns for the past year are omitted; and your Committee regret that the log of the 'Munster,' and the results attained by working out her performances,—although the calculations have involved considerable trouble to the Committee in their preparation,—have also to be omitted.

Your Committee have received from the Royal African Mail Company an abstract of the log of the screw steamship 'McGregor Laird' on her first voyage from Liverpool to Madeira, and the particulars of the vessel and her machinery. To the performances of this ship your Committee call especial attention, on account of the great economy exhibited in the consumption of fuel.

Foreign Mail Service.—Your Committee would call attention to the returns supplied of the performances of the steamships belonging to the Austrian Lloyds' Steamship Company; and although they are to some extent incomplete (which arises from no systematic recording having previously been adopted), this, it is promised, will be remedied in future by the adoption of the forms supplied by your Committee.

The Mercantile Marine Service.—Your Committee have been occupied principally in effecting arrangements by which a more thorough and extended organization of the means of obtaining returns of the performances of mercantile steamships employed in ocean navigation can be secured, and also in making personal application to many of the largest steamship-owners at the principal ports of Great Britain. They have succeeded in enlisting the active cooperation of many proprietors of steamships. In some cases the owners of mercantile marine ships, upon being called on by members of this Committee, at once requested their superintending engineers to adopt the "forms of returns" prepared by this Committee, and in other cases the result of such personal communication has been the suggestions of modifications in the "forms;" but, in all instances, or nearly so, the engineers have undertaken that, in future, a more perfect and systematic recording of the performance at sea shall be adopted, and that the results shall be regularly placed at the disposal of your Committee.

With a view of obtaining, with greater facility than heretofore, returns of performances, as well as the dimensions and particulars, of ships, engines, and machinery, your Committee have adopted a form of pocket-book, or "Engineers' Pocket Log," which contains a greater number of details than were included in their previous "forms of returns." This log is so arranged that the returns can be removed from the case when filled up, and the blank form inserted. Each book is furnished with a pocket to receive and preserve the indicator diagrams or "cards."

Although these books have only recently been issued, considerable numbers of them are in course of being filled up by the engineers of ocean-going steamships; and arrangements have been made for the regular transmission of these returns from each ship during the next twelve months. Since the issuing of these Pocket Logs, your Committee have received particulars of between 30 and 40 first-class ocean-going screw steamships, which were, however, received too late to be properly tabulated so as to accompany the present Report. These returns are being examined and arranged for publication. The Engineers' Pocket Logs have been freely circulated and well received, and they promise to yield a large amount of valuable information to the Association.

A list of the particulars asked for will be found in the Appendix.

The particulars of the 'Great Eastern' having been already published, the logs of her performances on her Transatlantic voyages have been regularly supplied to your Committee since she has been refitted and placed upon the North American service.

These logs have been collected, and are given in the Appendix to the present Report.

Performances of Vessels under Sail.—In compliance with the recommendation of the Council of the Association, your Committee have succeeded in obtaining promises of copies of the logs or returns of the performances of several of the largest sailing-ships belonging to the Australian, India, and China Packet Services, and to this end special observations are being made; and it is hoped that the results of the labours of those who have undertaken the duty of supplying your Committee with these returns may be included in the next Report in such a form as will render them available for comparison with the performances of full-powered and auxiliary steamships performing similar voyages.

Your Committee have received from the Earl of Durham the logs of the sailing schooner-yacht 'Beatrix,' on her Mediterranean voyages. The dimensions and particulars of this vessel, together with scale of displacement, have also been received, but not in time to be included in the Report.

Your Committee have been promised the particulars of some auxiliary-powered ocean steamships.

The Committee purpose to act upon a suggestion made to them, of forming a list of the Engineers of the several classes employed in the mercantile steam service, who have, with the sanction of the owners, supplied your Committee with returns of the performances of ships under their charge, to which reference may be had by such members of your Association as are interested in the subject, and with a view to afford opportunities for the advancement of such Engineers as have shown the greatest amount of scientific ability in connexion with their calling.

Your Committee have determined to act upon a suggestion by which the performances of some steamships, which are at present withheld, may i future be supplied for the use of the Committee, viz., that such returns sha be published under a distinguishing number, instead of publishing the name the vessel, her builders, and the constructors of her machinery, and that t latter particulars shall only be disclosed with the consent of the owners.

Your Committee continue to receive from steamship-owners and enginee invitations to be present at the trials of steamships.

The sum of £150, voted by the Council of the Association to defray t expenses of your Committee, has been expended and slightly exceeded.

Your Committee have thought it desirable to add the following particula of items to be included in a form of return to be printed, and circulated wi the logs and forms of returns issued by the Committee.

Position of centre of gravity of vessel.
Position of centre of buoyancy.
Position of metacentre for rolling.
Position of metacentre for pitching.
Wedges of immersion and emersion at an angle of 7½, or 15, or any othe number of degrees.
Approximate radius of gyration of vessel about longitudinal axis.
Approximate radius of gyration of vessel about transverse axis.
Number of rolling oscillations per minute.
Number of pitch oscillations in a minute.

Angles through which vessel rolls. Angles through which vessel pitches.	Under given circumstances, those angles to be measured not by a pendulum, plummet, or spirit-level, bu either by observing the horizon o the stars, or by a gyroscope.

Length, height, period and direction of waves at time of experiment, sai carried, indicated power at time of experiment, direction and force of wind.

A lithographed sheet has been added to the Appendix, containing nine indicator diagrams and a scale of displacements, as your Committee considered those elements to be necessary for the proper consideration of the returns and particulars furnished to them.

The other indicator diagrams, which have been received by your Committee too late to be embodied in the present Report, may be seen by any one interested therein on application at the Offices of the Committee.

The thanks of the Association are due to Colonel Paradis, the Technical Director of the Austrian Lloyds' Company, who, at the request of the Committee, caused the information in the Appendix relating to the vessels of this Company to be compiled expressly for insertion in the present Report.

The thanks of the Committee are also due to—

The Lords Commissioners of the Admiralty, the Secretary of the Admiralty, the Comptroller of the Navy, and the Engineer-in-Chief of the Admiralty, for such information as they have furnished, or permitted to be supplied to your Committee, relating to the trials and sea performances of vessels in Her Majesty's service.

To the heads of the various Departments of the Service, and to the officers under them, for the facilities afforded to your Committee in obtaining such information as the rules of the Service allow, or which have been specially permitted to your Committee.

To the Officers of Her Majesty's Navy, by whom returns have been fur-

"MACGREGOR LAIRD"

Scale of Capacity

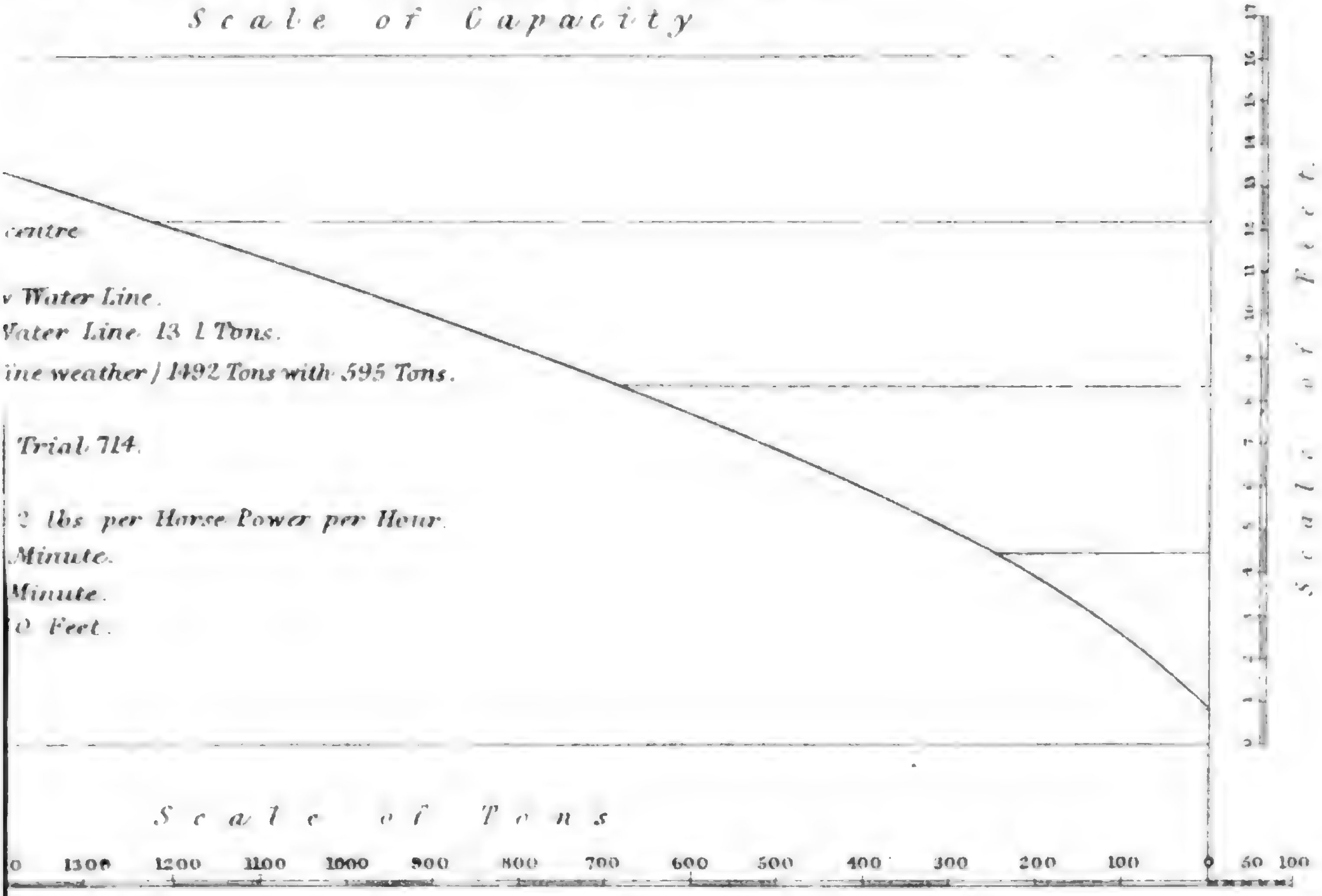
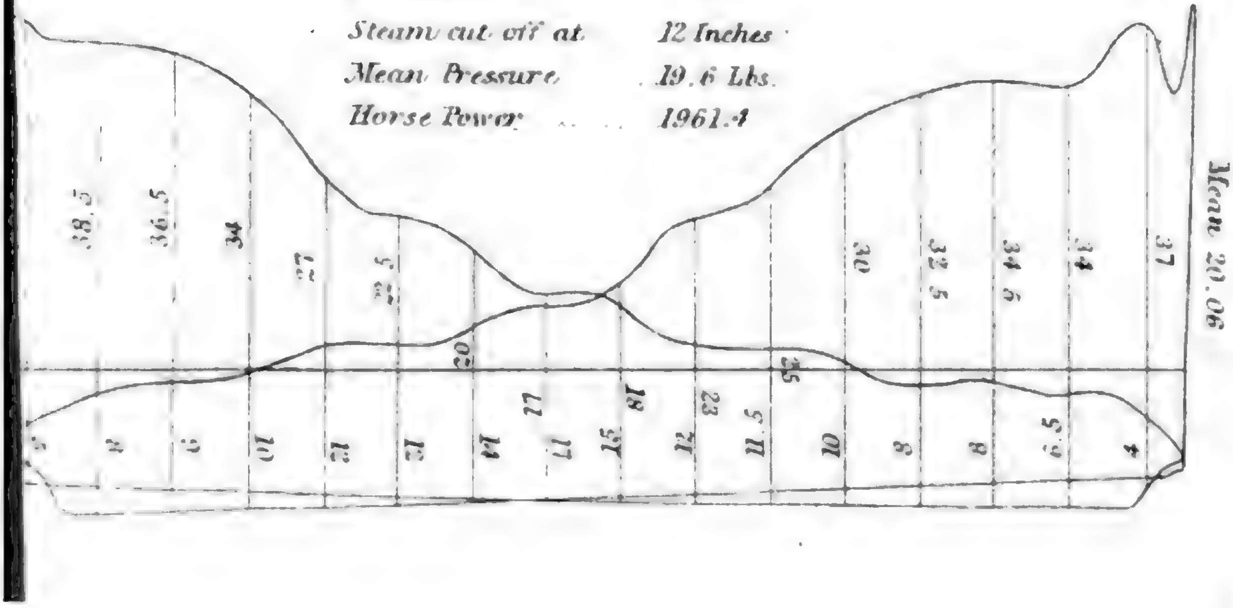


Diagram from Forward Engine of

S. S. "HANSA"

1st November 1861.

Steam	29 Lbs.
Vacuum	28 Inches
Revolutions	50
Steam cut off at	12 Inches
Mean Pressure	19.6 Lbs.
Horse Power	1961.4



nished; also to those who are at present engaged in recording the performance of Her Majesty's ships at sea, especially to the Royal Naval Engineers,—than whom a more thoroughly practical, highly intelligent, and valuable body of scientific officers does not exist in this or any other country,—for the assistance they have so readily afforded.

To the various Steamship Companies and Steamship Owners, and their Managers and Engineers, who have supplied returns.

The Meetings of your Committee during the year have been held at Stafford House, through the kindness of his Grace the Duke of Sutherland, and have been fully attended.

The thanks of the Association are again due to Mr. W. Smith, C.E., for his valuable aid. His offices have also been freely at the service of the Committee.

In conclusion, your Committee believe that their labours have already been productive of considerable advantage, that the objects with which they were appointed are being rapidly attained, and that, by continuing their labours, the machinery they have succeeded, after considerable trouble, in organizing will be productive of the utmost benefit to those engaged in steam navigation, and they have reason to believe that the future collection of the returns will be a comparatively easy task.

(Signed) SUTHERLAND,
Chairman.

Offices of the Committee,
19, Salisbury Street, Strand, London, W.C.

TABLE 25.—*Notes on the North German Lloyd Company's Steamship 'Hansa,' and her Performances on Trial, November 1st and 2nd,* 1861*. *Furnished by Messrs. Caird and Co., of Greenock.*

Dimensions, &c.—Length on load water-line, 330 ft.; beam, 42 ft.; depth, 33 ft. 6 in. (four decks). Displacement at $20\frac{1}{2}$ ft. draught of water, 4400 tons. Midship section at $20\frac{1}{2}$ do. =692 sq. ft.

Engines.—The cylinders are 80 in. diameter; stroke, 42 in.

Surface Condenser—Has brass tubes 1 in. external diameter, with a cooling surface of 6568 square feet.

Cold-water Pumps for supplying Condenser with Sea Water.—Two double-acting horizontal pumps, 21 in. diameter, and a stroke of 18 in., which can be increased to 24 in. It being found that this capacity of pump supplied too much water, eight holes, $1\frac{1}{4}$ diameter, were bored through each pump-piston. On the second trial, there was still sufficient water, and the pumps worked much easier and without any noise. The sea-water was forced through the brass tubes in condenser, and the steam was condensed on the external surface of the tubes.

Boilers.—There are sixteen furnaces in the four main boilers, with a grate surface of 350 square feet, and a total heating surface of 9400 square feet.

Auxiliary Boiler.—There are two furnaces, with a grate surface of 25 square feet, and a heating surface of 460 square feet (not in use on trial-trips).

The Superheater has a heating surface of 2000 square feet.

Pressure.—Safety-valves were loaded to a pressure of 30 lbs. per square inch.

The Propeller is three-bladed, 17 ft. diameter, with an increasing pitch varying from 29 to 32 ft.

Trial Trip.—On the 1st November, 1861, the 'Hansa' was tried be-

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* The indicator diagrams of this vessel will be found in the Appendix.

TABLE 19.—*Peninsular and Oriental Steam Navigation Company.*

Return showing the results of the Performance at Sea of the 'Mooltan' from Southampton to Alexandria and back, as compared with Six other Vessels in the same service, on three consecutive voyages.*

Name of Ship.	Propeller.	Length.	Breadth.	Mean Draught of Water.		Displacement.	Average Speed.	Average Consumption of Coal per hour.	Average Total Consumption of Coal.	Consumption of Coal out and home, assuming the ships to be all of the same displacement as the 'Mooltan,' and their speed uniform 10 knots per hour.	REMARKS.
		feet.	feet.	ft.	in.	tons.	knots.	lbs.	tons.	tons.	
Mooltan......	Screw.	348	39	19	4	3335	10·64	2574	630	559	Pressure of Steam in the 'Mooltan,' 20 lbs'
Delta	Paddle.	324	35	16	9	2448	10·52	3978	1003	1098	Average Consumption of Coal out and home of these six ships, 1495 tons.
Indus.........	Paddle.	241	34	18	0	1800	9·16	4726	1367	2281	
Pera	Screw.	303	42	18	6	2840	10·34	3875	990	1033	
Euxine	Paddle.	222	29	13	8	1560	9·54	3673	1016	1851	
Ceylon	Screw.	306	40	18	1	2930	9·48	4435	1270	1497	
Ellora	Screw.	261	36	16	7	2147	10·22	3651	942	1211	

* These particulars have been furnished to the Committee by Mr. E. Humphreys, of Deptford.

TABLE 21 A.—*Abstract of Trials made on the Undermentioned Ships in H.M. Service with Different kinds of Screws.*

	Date.	Draught of Water.				Indicated horse-power.	Mean Number of revolutions.	Speed.
		Forward.		Aft.				
		feet.	in.	feet.	in.			
SHANNON.								
6-bladed screw propeller	June 16th, 1862.	20	2	21	9	1946·73	49·0	11·250
4-bladed "	May 31st, 1862.	20	3	21	9	2020·86	53·166	11·553
3-bladed "	July 4th, 1862.	20	3	21	9	2052·56	56·083	11·492
Mangin "	May 20th, 1862.	20	3	21	9	2030·72	53·166	11·328
Common screw with leading corner cut off	May 20th, 1862.	20	3	21	9	2054·8	58·583	11·288
Ditto with leading and following corners cut off ...	May 20th, 1862.	20	3	21	9	2093·92	57·416	11·081
PSYCHE.								
Full boiler-power	August 12th, 1862.	9	7	10	6	1448·24	33·	14·543
Half "	August 12th, 1862.	9	7	10	6	251·06	29½	13·314

Particulars of the above vessels and their previous trials have already been given.

tween the Cloch and Cumbrae lights, a measured distance of 13·66 knots, which she accomplished in 61 minutes 50 seconds, equal to a speed of 13·25 knots per hour; revolutions from 47 to 50 per minute, with a steam-pressure in boilers varying from 26 to 29 lbs. per square inch. Draught of water being 20½ ft.

Consumption of Coal, &c.—On November 2nd the 'Hansa' was taken out again, and the steam kept at a pressure varying from 26 to 29 lbs. per square inch, the revolutions of the engines ranging from 48 to 50 per minute; and it was found that 8616 lbs. of coals, which were weighed on deck and lowered to the stoke-hole, kept the steam up at the pressure above named for 136 minutes. This is equal to a consumption of 3801 lbs. of coal per hour, or about 2 lbs. per horse-power. The coals used were from the best Welsh pits (Aberdare).

The Temperature of the Steam in the boilers was 272°; on leaving superheater, 340°; on entering cylinder, 280°. There being the facility for mixing the steam in this case, the steam from three boilers was supplied superheated; and the steam from the fourth passed direct to the cylinder. This was found to be necessary from the superheated steam being too dry for the packing and faces. The result of this will be seen from the diagrams in the Appendix.

Feed-water.—The temperature of feed-water about 80°, and the water to make good the waste that occurred by blowing off steam, &c., was supplied to the large boilers direct from the sea.

ENGINEER'S POCKET LOG.

The following are the particulars asked for in the "Engineer's Pocket Log" issued by the Committee on Steamship Performance.

Engines by
Running between and
Length of voyage—knots or statute miles.
The steamer.
Built by
In the year
Greatest speed under steam alone, in knots or statute miles.
Average duration of voyage, deducting stoppages.
Shortest time in which the voyage has been made.
Longest time taken to perform the voyage.
Kind of cargo carried.
Tons of cargo by weight.
Tons of cargo by measurement.
Supply of coals taken.
Is this for the double run?
Consumption of coals on one voyage.
Quality of coals used.
Oil—gallons per 24 hours.
Tallow—pounds per 24 hours.
Number of engineers.
Number of firemen.
Number of trimmers.

TABLE OF DISPLACEMENTS AND IMMERSED SECTIONS, FROM 1 FT. TO 28 FT.

Tonnage, builder's measurement.
Tonnage, register.
Weight of engines.
Weight of boilers without water.
Weight of water in boilers.
Weight of screw.
Weight of screw-shafts.
Vessel—length over all.
Beam.
Depth.
Length at load-line.
Breadth at ditto.
Draught at ditto.
The mean girth under water, as found by taking the mean of the girths, as measured on the "body-plan" of the vessel, of the immersed parts of a series of equidistant frames or cross sections.
Length of bows from "dead flat."
Length of stern from "dead flat."
Number of masts.
How rigged.
From top of bulwarks to load water-line.
Length of engine-room.
Length of boiler space.
Length of vessel taken up as coal-holes in addition to above.
Distance from engine to screw propeller.
Diameter of screw propellers.
Average pitch.
Pitch at circumference.
Pitch at boss.

Length fore and aft at boss.
Length fore and aft at point of blades.
Greatest width of blade.
Width of blade at boss.
Number of blades.
Screw is covered at aforesaid draught.
Is it a common screw?
Is it a Griffith's screw?
Are the blades curved?
State if there is anything peculiar in the configuration of the screw.
Paddle-wheels—Diameter over floats.
Length of floats.
Breadth of floats.
Thickness of floats.
Number of floats.
Centre of shaft above water-line.
Dip of floats.
If feathering floats.
Diameter between centre of floats.
Length of crank-arm on float.
Centre of feathering excentric to centre of shaft.
Ditto inches higher than centre of shaft, or inches lower than centre of shaft.
Description of engines.
Description of valves.
If geared, what is the multiple of gearing?
Or number of teeth in wheel and ditto in pinion.
Number of cylinders.
Diameter of piston.
Diameter of trunk.
Length of stroke.
Does trunk extend through both ends of cylinder?
Valves set to cut-off at
Number of steam-ports at each end.
Length of each.
Breadth of each.
Slide-valve travel.
Steam-cover at top.
Steam-cover at bottom.
If a V on end of valve, its breadth.
If a V on end of valve, its depth.
Steam lead at top.
Steam lead at bottom.
Exhaust-lap at top.
Exhaust-lap at bottom.
Exhaust-clearance at top.
Exhaust-clearance at bottom.
Is there link-motion?
Is there a separate expansion-valve?
Grades of cut-off measured from beginning of stroke.
Cut-off generally in use. (NOTE.—If the engines are on the high- and low-pressure principle, fill up as much of the preceding as is applicable, stating which cylinder is referred to, and also fill up the following.)
Description of compound engines.
Number of high-pressure cylinders.
Diameter of piston.
Diameter of trunk.
Length of stroke.
Does trunk extend through?
Steam is cut off at from beginning.
Exhaust opens at
Exhaust shuts at
Area of steam-ports.
Number of low-pressure cylinders.
Diameter of piston.
Diameter of trunk.
Length of stroke.
Does trunk extend through?
Steam is admitted at
Steam is cut off at
Exhaust opens at
Exhaust shuts at
Area of steam-ports. (NOTE.—As some of these quantities may be unknown, it will suffice to give particulars of valves, cover, lead, and travel, so that the cut-off can be found from them.)
Valves of compound engines.
Condensers—contents of each, including tubes, if any.
Number of condensers
Number of air-pumps.
Diameter of air-pump.
Diameter of its trunk, if any.
Does trunk extend through?
Stroke of air-pump.
Have the air-pumps foot-valves?
Are they double-acting?
Description of condenser.
If surface condenser, can it be also used as a jet condenser?
Total number of tubes.
Material.
Thickness.
Length of each between tube-plates.
Inside diameter of tubes.
Through what length of tubes does the water circulate?
Circulating-pumps, how many?
Are they double-acting?
Diameter of each.
Diameter of trunk, if any.
Length of stroke.
Diameter of suction-pipe to each pump.
Diameter of discharge-pipe from each pump.
Diameter of suction-valve on ship's side.
How much is it opened?
Boilers—number of pieces.
Total number of furnaces.
Total length of firebars over ends.
Width of each furnace.
Thickness of bars at top.
Width between bars at top.
Total air-space through bars in one furnace.
Area over bridges.
Bottom of ash-pit to top of dead plate.
Top of dead plate to crown of furnace at front.
At back, height of crown of furnace above bars.

From back tube-plate to back of fire-box.
From crown of furnace to top of fire-box.
Number of air-holes in furnace fronts and door.
Diameter of each.
Is there a slide on these?
From top of fire-box to crown of boiler.
From top of fire-box to top of steam-chest.
Size of steam-chest.
Steam room in each boiler in cubic feet.
With water-level, inches above fire-box crown.
Are the boilers dry-bottomed?
Number of tubes for each furnace, in height.
Ditto in width.
Ditto, left out for stays.
Length of tubes.
Inside diameter of tubes.
Material.
Chimney—diameter at uptake.
Number of chimneys.
Height from fire-bars to top of chimney.
Superheater. Is there a superheater?
At what temperature is the steam used?
Temperature of smoke in chimney.
Saltness of water in boilers.
Is there a feed-heater?
Temperature of the feed water.
Temperature of the hot-well.
Vacuum maintained.
What is the difference between the inches in the vacuum-gauge and the inches on the ship's barometer taken at the same time?
Pressure of steam in boilers.
When at full speed, what is the difference between the steam-gauges at the boilers and near the cylinders?
Is there a good command of steam?
Is there flame in the smoke-box?
Revolutions of engines per minute.
Please enclose indicator diagrams, and mark each one thus, or in some other intelligible way:—

A T	G	S	V	R	K	D	C Rushby Park	Ship's Name and Date
		14	23	45	12	13	7½	

which reads thus:—Aft engine top of piston; Grade of expansion ⅓; Steam-gauge 14; Vacuum-gauge 23; Revolutions of engine 45; Speed of vessel, in knots, per hour 12; Mean draught 13 ft.; Rushby Park Coals, per hour, 7½ cwts.

If the speed of vessel be given in statute miles, write M instead of K.

Instead of AT write AB, FT, FB, as the case may be. If convenient, after V insert $\frac{B}{29}$, which reads, Barometer 29 in.

You are also requested to fill up as many lines of the following Tables as you have an opportunity of doing.

Table of Performance under Trial, under Steam alone, under Sail alone, and under Steam and Sail combined.

Number of Trial.
Date.
Place.
Ship's course
Direction of wind.
Force of wind.
State of sea.
Duration of trials.
Area of sail set.
Description of sail set.
Average speed per hour.
Consumption of coal per hour.
Quality of coal.
Indicated horse-power.
Diagrams enclosed, No.
Draught of water.
Pitch of screw.
Screw covered.
Grade of expansion.
Steam-gauge.
Vacuum-gauge.
Barometer.
Revolutions per minute.
Number of furnaces at work.
Note.—Trials Nos. are under steam only, and Nos. under steam and sail combined.

On the Fall of Rain in the British Isles during the Years 1860 *and* 1861. *By* G. J. Symons, *M.B.M.S.*

Before entering on the consideration of the rainfall during the last two years, it will be well to offer a very few preliminary remarks on the various causes which affect the amount of rain collected, and also briefly to state in what manner the information given in the following Tables has been verified.

The first requirement is obviously that the gauge should be rigorously accurate, and placed in a suitable position; but it is equally obvious that the satisfactory fulfilment of these conditions can only be determined when every gauge has been visited and tested by some person well acquainted with the subject, and provided with the necessary apparatus. This examination, involving as it does the testing of more than 500 instruments, scattered far and wide over the British Isles, from Galway on the west to Norwich on the east, from the Shetland Isles to Guernsey, *cannot* be completed for several years, and is, moreover, not *indispensable*; for adjacent stations will generally enable us to determine if any large error attaches to either the instrument or its position. For the present, then, it is a matter, not of choice, but necessity to take the readings as recorded by the observers; and as the majority of the gauges already tested have borne the examination satisfactorily, it is presumed that this may be safely done.

In the next place, it is almost needless to say, that unless the height of the rain-gauge above the ground and above sea-level be known, the records are not comparable with other stations; for every foot of elevation above the ground is believed materially to diminish the amount collected, and every increase in the height above the sea-level to increase it. These particulars are therefore given wherever they are known; but the values must be received, subject to revision when the stations have been visited and the elevations accurately determined.

It is, of course, almost impossible to secure *perfect* accuracy in such an extended series of returns as are combined in the following Tables, but I believe they are very nearly perfect. The information was sent to me by the observers in reply to circulars issued at the close of each year; the returns, as received from them, were classified into counties and districts, examined, all errors being sent back for explanation, and copied into the following Tables, which have finally been checked against the observers' MS. returns.

The excessive rainfall in the Lake District of England having caused considerable interest, not to say incredulity, it may be well to add a few words in entire confirmation of the perfect veracity of the returns.

The gauges were mostly erected in 1844 or 1845, by Dr. Miller of Whitehaven, whose known accuracy might alone be a sufficient guarantee; but, besides this, there is the personal experience of those who, like myself, have studied the rainfall of that district, as alone it can be properly studied, dwelling amid the mountains and watching the effect of each summit on the drifting clouds, whether driven by a heavy gale or merely floating on a gentle breeze.

To make *certain* that the gauges were as accurate as when originally erected, I recently lent my friend Mr. G. H. Simmonds the necessary apparatus; he has carefully tested several of the gauges, and, so far as the calculations are concluded, we find them strictly accurate.

The stations have been arranged on the plan employed in the Reports of the Registrars-General of England and Scotland, except that the ordinary county boundaries are maintained, and that the stations in each county are arranged in the order of latitude from south to north. In Ireland, the arrangement is merely according to latitude.

The counties comprised in each district are enumerated in the following List, so that the fall at any station may be referred to in the general Tables with the greatest facility.

ENGLAND AND WALES.

Division I. Middlesex.—Middlesex.
,, II. South-eastern Counties.—Surrey, Kent, Sussex, Hants, Berks.
,, III. South Midland Counties.—Hertford, Bucks, Oxford, Northampton, Bedford, Cambridge.
,, IV. Eastern Counties.—Essex, Suffolk, Norfolk.

Division V. South-western Counties.—Wilts, Dorset, Devon, Cornwall, Somerset.
" VI. West Midland Counties.—Gloucester, Hereford, Shropshire, Stafford, Worcester, Warwick.
" VII. North Midland Counties.—Leicester, Rutland, Lincoln, Notts, Derby.
" VIII. North-western Counties.—Cheshire, Lancashire.
" IX. Yorkshire.—Yorkshire.
" X. Northern Counties.—Durham, Northumberland, Cumberland, Westmoreland.
" XI. Monmouthshire, Wales, and the Isles.—Monmouth, Glamorgan, Pembroke, Cardigan, Anglesey, Carnarvon, Flint, Guernsey, Scilly, Man.

SCOTLAND.

Division XII. Southern Counties.—Wigtown, Kirkcudbright, Dumfries.
" XIII. South-eastern Counties.—Selkirk, Peebles, Berwick, Haddington, Edinburgh.
" XIV. South-western Counties.—Lanark, Ayr, Renfrew.
" XV. West Midland Counties.—Stirling, Bute, Argyll.
" XVI. East Midland Counties.—Kinross, Fife, Perth, Forfar.
" XVII. North-eastern Counties.—Kincardine, Aberdeen, Elgin.
" XVIII. North-western Counties.—Ross, Inverness.
" XIX. Northern Counties.—Sutherland, Orkney, Shetland.

IRELAND.

Division XX. Ireland.—All the Counties whence returns have been received.

The fall at a few of the stations has been laid down on the accompanying Map, with the double object of illustrating the relative fall in different parts of the British Isles, and the relation, in each locality, between the fall in 1860 and 1861. This has been done in the following manner:—Darkly shaded discs uniformly represent the fall in 1861; lightly shaded, that in 1860. The radii of the circles are half the scale given on the Map; the *diameters* therefore increase as the fall; and hence the increased diameter of the circles immediately points out the places of heaviest fall. The relative frequency and extent to which either the darkly or lightly shaded circles extend beyond the others shows which year had the heavier fall; and the breadth of the annulus shows by how much it exceeded the other.

In selecting the stations for insertion in the Map, preference was given to those less than 200 feet above mean sea-level, and at which the gauge was within a few feet of the surface of the ground. It was not found consistent with good geographical distribution to adhere rigidly to these requirements in every case, but the exact height may be readily ascertained by reference to the general Tables. The fact, however, that the mean height of the selected gauges above the ground is, in England, 1 ft. 4 in.; in Scotland, 1 ft. 11 in.; and in Ireland (omitting Cork), 7 ft. 7 in.; and above the sea, 131, 177, and 108 ft. respectively, shows that a near approach has been made to the fulfilment of these conditions. The paucity of stations in Ireland necessitated the use of rather elevated gauges; in the case of Cork, the Map shows the fall *at* the ground computed from the fall observed 50 ft. above it, as otherwise it would not have been comparable.

It is remarkable, and perhaps suggestive, that in 1860 the excess in South Britain was counterbalanced by a deficiency in Scotland; and that in

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1861 the equipoise was maintained, but in the reverse order, England being comparatively dry, and Scotland (especially the western coast) subject to almost unprecedented rains. It is also most noteworthy that, if the returns from all the stations in England, Scotland, and Ireland are combined, the fall is nearly identical in the two years. In 1860, the average fall at 390 stations was 39·784 inches; and in 1861, 38·466 inches.

The singularity of this result is fully shown by Table I., which gives the average fall in each district for each year, and the excess or defect in each district of 1861 over 1860.

TABLE I.—Average fall of Rain in 1860 and 1861, and difference between the two years.

Division.	Number of Stations.	1860.	1861.	1861–1860.
		in.	in.	in.
England :— I. Middlesex	7	32·553	20·763	−11·790
,, II. South-eastern Counties	46	36·710	25·913	−10·797
,, III. South Midland Counties	20	30·221	21·505	− 8·716
,, IV. Eastern Counties	16	31·912	20·411	−11·501
,, V. South-western Counties	48	46·040	34·403	−11·637
,, VI. West Midland Counties	22	34·259	25·838	− 8·421
,, VII. North Midland Counties	32	32·059	23·598	− 8·461
,, VIII. North-western Counties	31	43·081	39·448	− 3·633
,, IX. Yorkshire	32	38·895	30·680	− 8·215
,, X. Northern Counties	24	50·941	52·357	+ 1·416
,, XI. Monmouthshire, Wales, &c.	6	48·550	41·110	− 7·440
Scotland :—XII. Southern Counties	4	49·075	55·087	+ 6·012
,, XIII. South-eastern Counties	12	30·332	30·862	+ 0·530
,, XIV. South-western Counties	16	40·573	52·701	+12·128
,, XV. West Midland Counties	12	52·278	63·377	+11·099
,, XVI. East Midland Counties	30	42·980	50·535	+ 7·555
,, XVII. North-eastern Counties	8	37·790	35·880	− 1·910
,, XVIII. North-western Counties	7	44·623	67·306	+22·683
,, XIX. Northern Counties	5	34·128	38·746	+ 4·618
Ireland : — XX. Ireland	12	38·692	38·813	+ 0·121
General average	390	39·784	38·466	− 1·318
England	284	38·656	30·548	− 8·108
Scotland	94	41·472	49·312	+ 7·840
Ireland	12	38·692	38·813	+ 0·121

The next point for consideration is the relation which subsists between the fall in the two years, 1860 and 1861, and the average of a long series of years. A large number of the gauges having only been in use for ten or

TABLE II.—Difference between mean Rainfall, as obtained from long series of years, and from the ten years, 1850 to 1859.

Division.	Name of Station.	Period of observation.	Total number of years.	Mean of the whole period.	Mean of ten years, 1850–59.	Difference per cent.
				inches.	inches.	
II.	Greenwich	1815–61	47	25·42	23·16	9
V.	Exeter, St. Thomas's	1814–61	48	32·80	31·15	5
VI.	Orleton	1831–61	31	29·18	28·82	1
VIII.	Bolton-le-Moors	1831–61	31	46·92	44·10	6
IX.	Halifax	1829–61	33	32·38	30·71	5
XV.	Rothesay	1800–61	62	48·31	45·97	5

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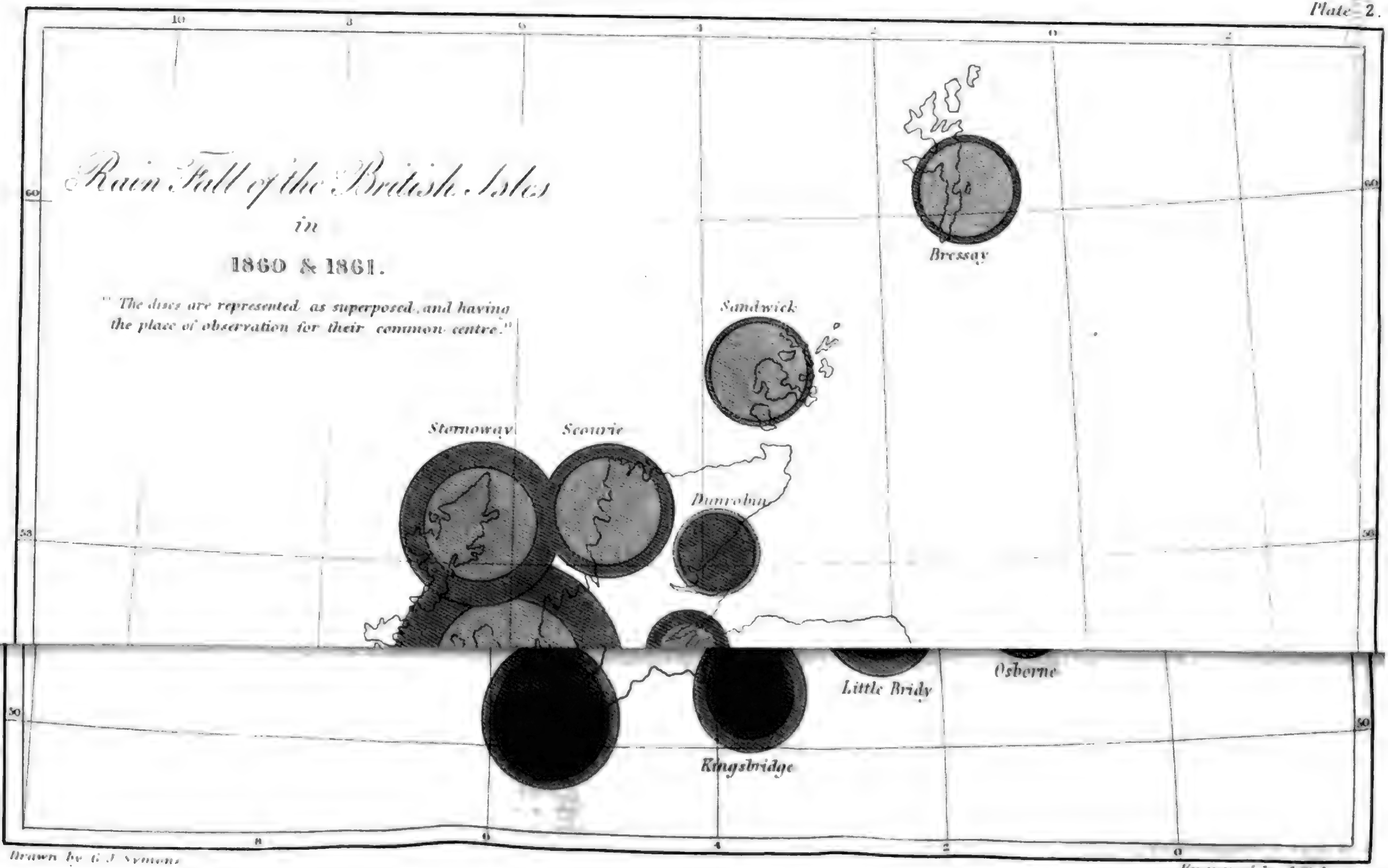

Rain Fall of the British Isles
in
1860 & 1861.

"The discs are represented as superposed, and having the place of observation for their common centre."

Bressay
Sandwick
Stornoway
Scourie
Dunrobin
Little Bridy
Osborne
Kingsbridge
10
8
6
4
2
0
2
60
58
50

Drawn by G. J. Symons

Engraved by J. W. Lowry

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fifteen years, it was found necessary to adopt, as a standard of comparison, the fall during the ten years, 1850 to 1859.

The fall during this period appears from Table II. to be very suitable for the purpose, as the amount during it was generally within 5 per cent. of the average fall during the last fifty years.

Tables III. and IV. give the results obtained by comparing the fall in 1860 and 1861 with this standard, and show (1) that at almost every station the fall in the two years was greater than the average, (2) that the excess was slight in Mid-England, larger in the South-west of England, the South-west of Scotland, the West of Ireland, and largest of all in the English Lake District.

Table III.—Excess of the Mean Rainfall for 1860 and 1861, above the average of the ten years, 1850–1859.

Division.	Station.	Excess.	Division.	Station.	Excess.
		inches.			inches.
I.	Chiswick	+ 2	VIII.	Stonyhurst	+ 3
	Enfield	+ 4		Coniston	+25
II.	Greenwich	+ 3	IX.	Redmires	+ 3
	Chichester	+ 4		Standedge	+ 3
	Ventnor	+ 3		Well Head	+ 2
	Southampton	+ 1		Leeds	+ 5
	Abbott's Ann	+ 1		Settle	+ 6
III.	Banbury	+ 2		Patrington	+ 3
	Cardington	+ 1		Wheldrake	+ 4
IV.	Epping	+ 5		Middleton	+ 4
	Witham	+ 2		York	+ 3
	Thwaite	+ 3	X.	Bishopwearmouth	+ 5
	Norwich	+ 3		Seathwaite	+35
	Burnham	+ 3		Kendal	+14
	Holkham	+ 2	XIII.	Thurston	+ 3
V.	Baverstock	+ 3		Glencorse	− 3
	Goodamoor	+ 9	XIV.	Bothwell Castle	− 2
	Tavistock	+ 5		Largs	+ 7
	Exeter, St. Thomas's	+ 4	XV.	Rothesay	+ 6
	Exeter Institution	+ 4		Castle Toward	+ 8
	Clysthydon	+ 2		Kilmory	+ 4
	Helston	+ 5	XVI.	Pittenweem	− 3
	Bodmin	+ 7		Deanston	+ 2
VI.	Cirencester	+ 2		Stanley	+ 3
	Shiffnal	+ 4		Craigton	+ 4
	Orleton	+ 5		Hill Head	+ 5
VII.	Wigston	+ 1		Seichen	+ 6
	Empingham	− 1	XVII.	Castle Newe	+ 7
	Derby	+ 3	XIX.	Sandwick	+ 3
VIII.	Liverpool	+ 0		Bressay	+ 3
	Bolton-le-Moors	+ 7	XX.	Portlaw	+ 9
	Preston (Howick)	+ 4		Killaloe	+11
	Preston (House of Correction)	+ 3		Black Rock	+ 4
				Markree	+ 9

Table IV.—Average Excess in each Division.

Division.	Excess.	Division.	Excess.	Division.	Excess.	Division.	Excess.
	inches.		inches.		inches.		inches.
I.	+3·00	VI.	+ 3·67	XI.	......	XVI.	+2·83
II.	+2·40	VII.	+ 1·00	XII.	......	XVII.	+7·00
III.	+1·50	VIII.	+ 7·00	XIII.	0·00	XVIII.	......
IV.	+3·00	IX.	+ 3·67	XIV.	+2·50	XIX.	+3·00
V.	+4·88	X.	+18·00	XV.	+6·00	XX.	+8·25

TABLES OF MONTHLY RAIN

ENGLAND AND WALES.

Division I.—Middlesex.

Middlesex.

1860.		Chiswick.	Whitehall.	Guildhall.	Guildhall.	St. John's Wood.	Camden Town
Height of Rain-gauge above	Ground..	....	....	5 ft. 0 in.	77 ft. 0 in.	0 ft. 0 in.	0 ft. 4 in.
	Sea-level.	....	....	51 ft.	123 ft.	161 ft.	100 ft.
		in.	in.	in.	in.	in.	in.
January		2·18	1·70	1·74	1·61	4·34	1·97
February		1·20	1·00	·95	·93	1·76	1·25
March		1·63	1·40	1·34	1·31	1·62	1·82
April		·95	1·50	1·46	1·36	1·58	1·50
May		3·04	2·70	2·58	2·43	2·88	3·57
June		5·15	5·20	5·84	5·38	6·21	5·47
July		2·72	2·00	1·67	1·48	2·12	2·26
August		4·16	4·00	4·56	4·16	4·66	4·48
September		2·82	2·50	2·86	2·65	2·70	2·92
October		1·60	1·50	1·53	1·40	1·68	1·77
November		2·60	2·00	2·24	2·08	2·65	2·72
December		2·03	2·00	2·14	....	2·40	2·51
Totals		30·08	27·50	28·91	....	34·60	32·24

Division II.—South-Eastern Counties (*continued*).

Surrey (*continued*).

1860.		Deepdene, Dorking.	Brockham, Betchworth.	Cobham.	Kew Observatory.	Wandsworth.	Battersea
Height of Rain-gauge above	Ground..	2 ft. 9 in.	0 ft. 6 in.	0 ft. 6 in.	0 ft. 0 in.	5 ft. 0 in.	0 ft. 0 in.
	Sea-level.	....	130 ft.	110 ft. ?	18 ft.	58 ft.	13 ft.
		in.	in.	in.	in.	in.	in.
January		3·80	3·35	2·65	2·36	2·09	2·00
February		1·47	1·12	·78	1·03	1·39	1·01
March		2·23	2·46	2·29	1·66	2·01	1·55
April		2·97	1·58	1·75	1·40	1·46	1·73
May		3·15	3·17	3·10	2·56	3·24	2·68
June		7·00	5·31	6·82	5·35	5·84	5·58
July		1·95	2·05	1·67	2·82	2·21	2·04
August		4·35	4·22	3·55	4·89	4·82	2·76
September		3·20	2·84	3·00	2·02	3·36	2·92
October		2·00	1·98	1·49	1·22	1·83	1·83
November		2·08	2·89	2·35	1·96	2·54	1·65
December		3·23	2·15	2·12	1·45	2·07	2·51
Totals		37·43	33·12	31·57	28·72	32·86	28·26

LL IN THE BRITISH ISLES.

ENGLAND AND WALES.

Division I.—Middlesex (*continued*).					Div. II.—S.-Eastern Counties.		
Middlesex (*continued*).					Surrey.		
ackney.	Finchley Road.	Finchley Road.	Tottenham.	Enfield Vicarage.	Ham, Red Hill.	Wonerah, Bramley.	Kitlands, Dorking.
ft. 6 in. 40 ft.	0 ft. 4 in. 270 ft.	36 ft. 4 in. 306 ft.	0 ft. 3 in. 60 ft.	30 ft. 0 in. 140 ft.	0 ft. 4 in.	0 ft. 0 in.	4 ft. 8 in. 580 ft.
in.	in.	in.	in.	in.	in.	in.	in.
2·20	....	....	2·48	3·44	3·46	2·40	3·56
1·80	....	....	1·49	1·58	·95	2·30	1·29
2·00	....	....	2·07	2·34	2·64	1·75	1·96
1·20	....	....	1·47	1·27	2·49	1·56	2·41
3·60	....	....	3·88	4·01	3·11	3·14	3·13
5·60	....	....	5·85	5·43	5·37	7·02	7·19
2·60	....	....	2·05	1·82	2·49	2·40	3·42
4·40	4·86	3·87	5·28	7·34	4·31	4·47	5·26
3·10	2·90	2·25	2·66		1·90	3·45	4·02
1·60	1·63	1·11	1·68	2·03	2·62	2·40	2·75
2·60	2·80	2·36	2·76	2·78	3·01	3·54	2·39
2·40	2·35	1·86	2·70	2·53	2·40	3·71	2·69
33·10	....	....	34·37	34·57	34·75	38·14	40·07

Division II.—South-Eastern Counties (*continued*).

Kent.							Sussex.
Dover.	Hunton Court, Staplehurst.	Linton Park, Staplehurst.	Tunbridge.	Maidstone.	Welling, Bexley Heath.	Greenwich Observatory.	Aldwick, Bognor.
ft. 8 in. 30 ft.?	0 ft. 8 in.	0 ft. 6 in. 200 ft.?	0 ft. 0 in. 125 ft.	4 ft. 0 in. 60 ft.	6 ft. 0 in. 150 ft.?	0 ft. 5 in. 155 ft.	0 ft. 0 in. ....
in.	in.	in.	in.	in.	in.	in.	in.
3·99	3·37	2·87	2·04	2·97	1·60	1·80	2·23
1·82	1·16	1·40	1·17	1·60	1·05	1·10	·64
2·80	1·93	2·61	2·55	2·71	1·89	1·90	1·02
1·79	2·52	2·84	2·75	3·04	1·21	1·00	2·20
4·03	3·03	3·12	2·79	3·32	3·12	3·90	3·13
3·31	4·63	5·09	5·06	5·36	5·63	5·80	5·60
1·90	1·71	2·07	2·49	1·58	2·53	2·80	2·65
3·75	2·80	3·54	3·52	3·69	3·25	3·70	3·23
3·69	2·59	3·36	2·48	2·89	2·48	3·10	2·30
2·18	1·60	1·71	1·75	1·63	1·50	1·60	1·96
3·25	2·64	2·67	2·44	2·59	2·36	2·50	2·24
3·74	2·40	2·38	2·39	2·27	2·10	2·80	2·20
36·25	30·38	33·66	31·43	33·65	28·72	32·00	29·40

ENGLAND AND WALES.

Division II.—South-Eastern Counties (*continued*).

Sussex (*continued*).

1860.		Worthing.	Thorney Island, Emsworth.	Chichester Museum.	Shopwyke, Chichester.	Glynde, Lewes.	Bleak H Hastings
Height of Rain-gauge above	Ground ..	0 ft. 0 in.	0 ft. 6 in.	0 ft. 6 in.	1 ft. 3 in.	....	4 ft. 0 in.
	Sea-level.	10 ft.	10 ft.	20 ft.	72 ft. ?	....	80 ft.
		in.	in.	in.	in.	in.	in.
January		4·66	2·25	3·71	3·58	5·08	4·36
February		·65	·78	·95	·91	1·29	·76
March		1·70	1·74	2·16	2·01	2·08	2·23
April		1·82	1·70	1·31	1·15	1·98	1·95
May		3·41	2·81	3·55	3·85	3·65	3·46
June		4·98	6·11	5·07	5·00	4·78	3·15
July		1·84	3·18	3·43	2·90	3·50	2·72
August		3·70	3·10	3·87	4·21	5·41	3·49
September		3·02	3·30	4·17	3·75	4·53	4·92
October		2·45	1·41	2·35	2·40	2·38	2·73
November		2·76	2·72	3·19	3·54	3·18	2·68
December		3·33	4·04	3·68	4·21	2·44	1·80
Totals		34·32	33·14	37·44	37·51	40·30	34·25

Division II.—South-Eastern Counties (*continued*).

Sussex (*continued*).

1860.		Chilgrove, Chichester.	St. John's College, Hurstpierpoint.	Uckfield.	Buxted Park.	Rectory, Maresfield.	Forest Lodge, Maresfield
Height of Rain-gauge above	Ground ..	0 ft. 6 in.	0 ft. 0 in.	6 ft. 0 in.	....	1 ft. 0 in.	1 ft. 0 in.
	Sea-level.	284 ft. ?	120 ft.	200 ft.	....	250 ft.	300 ft.
		in.	in.	in.	in.	in.	in.
January		4·34	....	4·75	4·70	4·55	4·16
February		1·50	....	1·50	1·34	1·28	1·00
March		2·18	....	3·00	3·35	2·38	2·15
April		1·75	....	2·53	3·07	2·52	2·51
May		3·85	2·96	4·20	4·36	3·41	3·45
June		6·72	....	4·80	5·20	5·17	5·41
July		2·88	....	3·00	3·10	2·61	2·55
August		5·05	4·60	5·84	5·53	5·56	5·84
September		3·86	3·22	3·75	4·76	4·05	4·04
October		2·86	2·31	2·97	3·31	2·70	2·46
November		3·60	2·56	2·95	3·68	3·11	2·51
December		3·41	....	3·17	3·15	3·36	2·94
Totals		42·00	....	42·46	45·55	40·70	39·02

ENGLAND AND WALES.

Division II.—South-Eastern Counties (*continued*).

Sussex (*continued*).							
High ickham, Hastings.	39 Tower, Hastings.	Marina, St. Leonards.	Fairlight.	Funtington, Chichester.	Slindon.	Dale Park, Arundel.	Westdean, Chichester.
ft. 0 in. 212 ft.	0 ft. 0 in. 0 ft.	0 ft. 0 in. 10 ft.	0 ft. 9 in. 498 ft.	....	1 ft. 0 in. 190 ft.	4 ft. 0 in. 316 ft.	0 ft. 6 in. 250 ft.
in.	in.	in.	in.	in.	in.	in.	in.
3·82	3·95	3·45	3·07	3·00	4·11	4·59	4·52
·97	·95	1·03	·93	·80	1·22	·80	1·37
1·61	2·10	1·83	1·68	1·50	2·80	2·90	3·03
2·17	2·25	2·25	1·99	1·48	1·50	1·71	2·04
3·20	3·16	3·08	3·16	3·47	3·97	4·52	4·53
3·62	3·72	3·60	3·49	6·14	6·14	6·65	7·06
2·39	2·69	2·50	2·21	1·50	3·00	3·23	2·98
3·42	2·98	2·67	2·28	4·74	5·00	6·46	5·68
4·29	4·00	3·96	4·25	3·19	4·73	5·09	5·15
2·00	2·90	2·17	1·92	3·39	2·84	3·32	3·35
2·79	2·05	2·31	2·32	3·34	3·30	3·89	4·07
2·38	2·70	1·92	2·24	2·95	5·45	1·93	5·16
32·66	33·45	30·77	29·54	35·50	44·06	45·09	48·94

Division II.—South-Eastern Counties (*continued*).

Sussex (*continued*).		Hampshire.					
Fair Oak, Rogate.	Crawley.	Ventnor, Isle of Wight.	Ryde, Isle of Wight.	Osborne, Isle of Wight.	Fareham.	Lyndhurst.	Ordnance Survey Office, Southampton.
ft. 6 in.	5 ft. 0 in. 300 ft.	3 ft. 0 in. 150 ft.	0 ft. 0 in. 110 ft.	0 ft. 10 in. 172 ft.	0 ft. 0 in. 26 ft.	....	0 ft. 0 in. 75 ft.
in.	in.	in.	in.	in.	in.	in.	in.
4·65	5·08	3·66	3·90	4·10	3·70	4·16	5·08
1·60	1·48	·90	1·07	·83	·70	·90	1·15
1·85	2·92	3·08	3·56	2·19	3·70	2·46	2·33
2·17	2·48	1·94	1·14	1·60	·90	1·15	1·87
1·62	3·49	3·54	3·09	3·30	2·90	3·51	3·50
9·46	7·76	4·77	5·63	5·38	7·60	6·90	8·07
2·80	3·97	2·10	2·80	2·39	2·50	2·53	3·33
4·94	5·89	3·06	3·16	4·41	4·00	3·35	4·53
7·10	4·01	4·01	4·22	4·08	5·00	3·08	3·91
	3·30	2·42	3·07	2·30	3·60		2·09
3·21	3·45	3·05	3·34	3·46	2·20	2·48	3·16
5·18	3·80	3·65	1·30	3·20	5·20	2·34	5·03
44·58	47·63	36·18	36·28	37·24	42·00	32·86	44·05

ENGLAND AND WALES.

Division II.—South-Eastern Counties (*continued*).

Hampshire (*continued*).

1860.		Ordnance Survey Office, Southampton.	Gas-Works, Southampton.	Petersfield.	Petersfield.	Itchen Abbas.	Selborne
Height of Rain-gauge above	Ground	18 ft. 6 in.	10 ft. 0 in.	....	0 ft. 0 in.	3 ft. 0 in.	4 ft. 0 in.
	Sea-level.	94 ft.	20 ft.	....	200 ft.	....	400 ft.
		in.	in.	in.	in.	in.	in.
January		3·60	3·23	4·84	4·60	3·84	[illegible]
February		·87	·38	1·01	1·84	1·25	1·54
March		1·68	2·09	3·20	2·53	2·45	1·08
April		1·47	·79	1·36	1·86	·48	1·36
May		2·84	2·64	3·93	3·54	3·54	2·64
June		6·71	5·54	9·75	8·90	6·43	[illegible]
July		2·74	2·43	2·80	2·75	3·56	4·29
August		3·67	3·56	5·85	5·33	4·85	5·19
September		3·42	2·75	5·15	5·15	3·67	4·32
October		1·61	1·23	5·72	3·38	2·35	3·05
November		2·67	2·47	4·53	3·63	3·78	3·89
December		4·43	2·45	4·93	5·13	3·10	4·13
Totals		35·71	29·56	53·07	48·64	39·30	42·05

Division III.—South Midland Counties (*continued*).

		Hertford (*continued*).		Bucks.		Oxfordshire.	
1860.		Berkhampstead.	Royston.	Hartwell House, Aylesbury.	Hartwell Rectory, Aylesbury.	Rose Hill, Oxford.	Rad[illegible] Observ[illegible] Oxford
Height of Rain-gauge above	Ground	1 ft. 6 in.	0 ft. 7 in.	1 ft. 0 in.	4 ft. 0 in.	7 ft. 9 in.	0 ft. 0 in.
	Sea-level.	370 ft.	267 ft.	250 ft.	290 ft.	270 ft.	210 ft.
		in.	in.	in.	in.	in.	in.
January		3·60	2·59	2·93	2·64	2·89	[illegible]
February		1·50	1·13	·82	·31	1·17	[illegible]
March		2·12	2·18	1·86	1·31	1·81	1·89
April		1·12	1·38	1·24	·97	·74	·58
May		4·68	3·41	4·12	3·14	3·45	2·78
June		6·04	4·45	4·86	5·07	4·86	5·10
July		1·50	1·42	1·23	·87	1·60	2·38
August		4·54	3·85	4·69	3·92	2·37	3·79
September		3·39	3·03	3·84	3·93	1·83	2·53
October		1·94	1·21	1·92	1·75	·78	1·57
November		2·81	2·43	2·54	2·05	2·31	3·23
December		3·00	2·48	1·40	2·25	1·58	2·62
Totals		36·24	29·56	31·45	28·21	25·39	31·01

ENGLAND AND WALES.

iv. II.—South-Eastern Counties (*continued*).					Div. III.—S. Mid. Counties.		
pshire (*continued*).		Berkshire.			Hertford.		
bott's Ann, dover.	Aldershott.	R. M. Coll., Sandhurst.	White Waltham, Maidenhead.	Long Wittenham.	Watford.	Gorhambury.	Hemel-Hempstead.
. 4 in. 77 ft.	3 ft. 0 in. 325 ft.	5 ft. 0 in. 246 ft.	1 ft. 0 in.?	1 ft. 0 in. 170 ft.	5 ft. 6 in. 250 ft.?	2 ft. 9 in.	3 ft. 0 in. 250 ft.
n.	in.	in.	in.	in.	in.	in.	in.
3·19	3·12	2·62	1·97	3·03	4·22	3·74	3·53
·96	·75	·94	1·11	1·02	1·43	1·32	1·22
1·58	2·15	2·01	1·74	2·04	2·97	2·51	2·32
1·20	1·64	1·04	·63	·84	1·10	1·25	1·32
2·81	2·35	2·45	2·80	2·57	4·41	3·71	3·67
4·70	5·49	4·59	4·07	5·30	6·45	6·55	6·10
1·79	1·77	1·91	1·74	1·26	1·98	1·57	2·22
5·02	4·75	4·73	4·60	4·01	4·40	4·67	4·44
2·46	3·41	3·00	2·72	2·70	2·33	1·58	2·65
1·39	1·81	1·40	1·82	1·62	1·52	1·76	1·65
2·79	3·10	2·75	2·43	2·93	2·33	2·76	2·70
2·28	3·08	2·40	3·21	3·37	1·86	2·66	2·40
0·17	33·42	29·84	28·84	30·69	35·00	34·08	34·22

Division III.—South Midland Counties (*continued*).							
Oxfordshire (*continued*).			Northampton.			Bedfordshire.	
dcliffe rvatory, xford.	Banbury.	Banbury.	Althorpe House.	Welling-borough.	Marholm, Peter-borough.	Aspley, Woburn.	Cardington.
ft. 0 in. 30 ft.	7 ft. 4 in. 350 ft.	4 ft. 9 in. 340 ft.	3 ft. 0 in.?	0 ft. 2 in.	0 ft. 6 in.	0 ft. 6 in. 460 ft.	....
n.	in.	in.	in.	in.	in.	in.	in.
2·70	3·53	3·53	2·48	2·74	2·98	3·25	2·44
·90	1·29	1·29	1·00	1·12	·92	1·31	1·17
1·50	2·08	2·08	2·02	2·02	1·76	2·09	1·46
·52	·69	·70	·59	·81	·53	1·06	·72
2·43	3·54	3·37	3·08	2·94	3·11	3·89	3·17
4·46	4·36	4·33	4·60	5·35	5·41	5·07	4·28
1·98	1·68	1·52	1·22	1·60	2·22	1·11	1·31
3·69	4·14	3·91	3·64	3·68	4·10	3·51	2·71
2·21	3·40	3·47	2·80	3·11	3·33	3·96	2·88
1·50	1·89	1·92	1·22	1·76	4·31	1·47	1·33
2·92	2·71	2·82	1·43	2·32	2·54	2·52	1·97
2·07	2·61	2·62	1·12	1·96	1·88	1·99	1·64
6·88	31·92	31·56	25·20	29·41	33·09	31·23	25·08

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ENGLAND AND WALES.

Div. III.—S. Mid. Counties (*cont.*).			Division IV.—Eastern Counties.			
Bedfordshire (*continued*).		Cambridge.	Essex.			
1860.	Bedford.	North Brink, Wisbech.	Epping.	Dorward's Hall, Witham.	Frating, Colchester.	Dunmow.
Height of Rain-gauge above } Ground.. Sea-level.	3 ft. 6 in. 104 ft.	0 ft. 8 in. 11 ft.	6 ft. 0 in. 360 ft.	1 ft. 6 in. 20 ft.	....	.... 100 ft.?
	in.	in.	in.	in.	in.	in.
January	2·50	3·13	2·23	1·12	2·21	2·56
February	1·21	1·25	1·48	1·60	1·05	1·18
March	1·51	2·48	1·64	1·85	1·73	2·15
April	·76	·90	1·08	1·39	1·45	1·20
May	3·22	3·61	3·27	3·74	3·58	4·43
June	4·33	5·59	7·60	3·83	4·55	4·55
July	·92	1·24	2·95	2·69	3·43	1·50
August	3·10	2·75	6·15	2·61	3·90	3·05
September	2·50	2·79	3·20	2·22	1·85	2·45
October	1·26	1·93	1·95	1·46	1·38	1·35
November	1·99	2·33	2·35	2·41	2·72	2·53
December	1·65	2·86	3·13	1·16	1·85	1·98
Totals	24·95	30·86	37·03	26·08	29·70	28·93

Division IV.—Eastern Counties (*continued*).				Div. V.—S.-Western Cos.		
Norfolk (*continued*).				Wiltshire.		
1860.	Burnham.	Holkham.	Holkham.	Alderbury, Salisbury.	Baverstock, Salisbury.	Longbri- Deveril, Warminste
Height of Rain-gauge above } Ground.. Sea-level.	4 ft. 6 in. 102 ft.	0 ft. 0 in. 39 ft.	4 ft. 0 in. 43 ft.	0 ft. 6 in.	3 ft. 0 in.	....
	in.	in.	in.	in.	in.	in.
January	3·36	3·60	3·07	4·24	3·35	5·95
February	1·94	2·00	1·66	1·07	1·15	1·60
March	2·86	2·55	2·32	2·35	2·70	1·94
April	·99	1·00	1·00	1·00	1·75	1·51
May	4·14	3·75	3·65	3·38	3·30	2·12
June	4·40	4·30	4·16	5·88	6·75	4·66
July	1·63	2·00	2·00	1·50	1·50	2·79
August	3·51	3·53	3·32	3·56	4·90	5·33
September	3·54	3·13	3·19	2·58	3·05	2·83
October	2·77	2·55	2·37	1·76	2·00	3·08
November	3·16	3·00	2·64	2·43	2·70	3·68
December	2·35	3·28	2·20	4·37	4·30	4·83
Totals	34·65	34·69	31·58	34·12	37·45	40·32

ENGLAND AND WALES.

Division IV.—Eastern Counties (*continued*).

Essex continued).	Suffolk.					Norfolk.	
Bocking, Braintree.	Bury St. Edmunds.	Westley near Bury.	Thwaite.	The Lodge, Thurston.	Nether Hall, Thurston.	Norwich.	Egmere, Fakenham.
.... 200 ft.?	2 ft. 0 in.	1 ft. 6 in.	3 ft. 6 in. 150 ft.	2 ft. 0 in.	2 ft. 6 in.	0 ft. 0 in. 30 ft.	4 ft. 0 in. 150 ft.?
in.	in.	in.	in.	in.	in.	in.	in.
2·42	2·21	2·34	3·95	2·87	3·23	2·53	2·81
1·20	1·04	1·22	1·33	·88	1·21	2·50	1·96
2·11	2·49	2·81	3·56	2·06	2·84	2·97	2·50
1·24	1·01	1·01	1·03	·99	1·13	1·39	1·12
4·28	3·19	3·10	4·27	3·13	3·46	3·53	3·04
5·09	6·00	4·40	5·60	4·36	4·34	4·45	3·34
1·70	2·63	2·47	2·14	1·67	2·00	2·43	2·33
4·54	4·75	4·42	4·44	4·63	2·50	3·42	3·41
2·55	2·67	2·59	2·32	2·14	2·17	3·42	3·17
1·36	1·39	1·55	1·99	2·33	1·78	1·75	2·16
2·55	2·02	2·16	3·40	2·74	2·50	3·34	3·08
2·38	2·22	2·29	2·57	1·63	2·29	2·74	2·46
31·42	31·62	30·36	36·60	29·43	29·45	34·47	31·38

Division V.—South-Western Counties (*continued*).

Viltshire (*continued*).		Dorsetshire.					Devonsh.
Chapmans-lade, ear Corsely.	Castle House, Calne.	Portland.	Encombe, Purbeck.	Little Bridy.	Bridport.	Netherbury.	The Knowle, Kingsbridge.
4 ft. 7 in.	0 ft. 11 in. 321 ft.	2 ft. 0 in. 52 ft.	1 ft. 0 in. 150 ft.	0 ft. 4 in. 348 ft.	0 ft. 11 in. 95 ft.?	0 ft. 0 in. 50 ft.?	0 ft. 6 in. 143 ft.
in.	in.	in.	in.	in.	in.	in.	in.
4·05	....	3·43	4·50	5·42	3·86	5·68	2·99
1·41	....	·78	} 4·25 {	1·61	·97	1·37	1·59
2·55	....	2·48		3·32	2·73	2·88	3·30
2·15	1·79	1·80	2·00	3·04	2·36	2·20	1·55
2·72	3·32	3·01	4·20	4·36	3·25	3·84	3·90
6·64	6·26	5·20	6·48	7·47	5·52	6·50	8·09
2·44	1·32	1·87	1·82	2·57	1·62	1·76	1·62
6·01	5·18	2·98	4·95	5·27	4·01	4·49	5·22
2·60	2·57	1·71	4·43	3·64	2·40	2·65	3·07
3·03	1·70	1·37	2·60	2·01	1·45	2·35	2·08
3·01	2·56	2·67	2·45	3·94	3·28	3·69	4·11
3·70	4·68	3·47	4·97	6·38	5·18	4·96	4·92
40·31	....	30·77	42·65	49·03	36·63	42·37	42·44

ENGLAND AND WALES.

Division V.—South-Western Counties (*continued*).

Devonshire (*continued*).

1860.	Ham, Plymouth.	The Gardens, Saltram.	Ridgeway, Plympton.	Torrhill, Ivybridge.	Goodamoor, Plympton.	Crapstone, Buckland Monachorum.
Height of Rain-gauge above Ground..	3 ft. 0 in.	0 ft. 3 in.	0 ft. 6 in.	0 ft. 4 in.	0 ft. 2 in.	....
Height of Rain-gauge above Sea-level.	94 ft.	96 ft.	116 ft.	260 ft.?	580 ft.	500 ft.
	in.	in.	in.	in.	in.	in.
January	7·51	7·13	7·69	7·49	8·02	8·45
February	1·86	2·11	2·17	1·96	2·56	2·38
March	4·38	4·75	4·84	4·54	5·56	4·70
April	1·50	2·95	1·66	1·60	2·30	1·77
May	5·33	5·61	5·87	5·02	6·68	6·20
June	8·30	9·28	9·81	6·82	11·42	9·80
July	2·70	2·70	4·22	2·71	4·16	3·60
August	7·09	7·37	7·68	7·19	9·16	8·31
September	2·90	3·00	3·31	2·54	4·02	4·30
October	2·23	2·93	3·19	3·92	4·20	3·81
November	2·99	4·00	4·23	5·57	5·28	5·23
December	8·79	5·75	7·72	4·95	8·66	7·30
Totals	55·58	57·58	62·39	54·31	72·02	65·85

Division V.—South-Western Counties (*continued*).

Devonshire (*continued*).

1860.	Albert Terrace, Exeter.	High Street, Exeter.	Institution, Exeter.	St. Leonards, Exeter.	St. Thomas's, Exeter.	Clyst-Hydon.
Height of Rain-gauge above Ground..	0 ft. 0 in.	40 ft. 0 in.	13 ft. 7 in.	20 ft. 0 in.	3 ft. 0 in.	0 ft. 6 in.
Height of Rain-gauge above Sea-level.	160 ft.	170 ft.	155 ft.	160 ft.	50 ft.	200 ft.?
	in.	in.	in.	in.	in.	in.
January	....	3·98	4·02	....	5·11	4·24
February	....	·87	·90	....	1·36	1·24
March	....	2·70	3·00	....	3·48	3·15
April	....	1·74	1·32	....	1·25	2·14
May	....	2·88	3·42	....	4·57	3·88
June	....	6·92	6·48	7·09	8·04	6·14
July	....	1·63	1·72	1·65	1·90	1·84
August	3·86	3·55	3·32	3·33	2·26	4·67
September	1·95	1·65	1·56	1·75	1·78	3·26
October	1·46	1·22	1·12	1·22	1·61	1·80
November	3·83	3·60	3·96	3·53	4·68	3·07
December	7·40	5·52	5·26	4·58	6·13	6·10
Totals	....	36·26	36·08	....	42·17	41·53

ENGLAND AND WALES.

Division V.—South-Western Counties (*continued*).

Devonshire (*continued*).							
Torquay.	Highwick, Newton Bushel.	Dartmoor.	Teignmouth.	Teignmouth.	Library, Tavistock.	Dawlish.	Bovey-Tracey.
1 ft. 0 in. 150 ft.	1 ft. 6 in. 300 ft.?	40 ft. 0 in. 1380 ft.	1 ft. 1 in. 60 ft.	0 ft. 3 in. 25 ft.	45 ft. 0 in. 298 ft.	0 ft. 8 in. 62 ft.	0 ft. 6 in. 100 ft.
in.	in.	in.	in.	in.	in.	in.	in.
4·56	6·10	7·73	3·38	3·85	6·44	3·74	6·92
1·00	1·42	1·94	·75	1·32	1·49	1·24	1·63
2·11	3·78	4·58	2·17	3·27	2·75	3·88	4·72
1·03	1·63	1·16	1·19	1·26	1·57	2·22	1·84
3·21	4·27	7·59	2·16	2·05	4·48	2·78	3·96
6·67	8·87	10·36	6·80	8·27	8·10	9·35	9·09
·59	1·53	3·12	.........*	1·98	2·84	1·33	1·94
3·21	4·40	6·89	....	3·69	6·40	2·80	5·06
2·48	2·37	5·23	....	2·50	2·41	3·67	1·99
1·48	2·29	3·93	....	2·04	2·38	1·66	2·53
4·06	4·74	5·55	....	2·50	3·42	2·00	5·62
5·96	6·62	5·80	....	7·62	5·71	6·21	4·52
36·36	48·02	63·88	....	40·35	47·99	40·88	49·82

Division V.—South-Western Counties (*continued*).

Devonshire (*continued*).					Cornwall.		
Broadhembury, Honiton.	Tiverton.	Huntsham Court.	Castle Hill, South Molton.	Barnstaple.	Helston.	Penzance.	Tehidy Park, Redruth.
2 ft. 4 in.	0 ft. 2 in. 400 ft.?	1 ft. 1 in. 584 ft.	3 ft. 0 in. 160 ft.	0 ft. 6 in. 31 ft.	5 ft. 0 in. 110 ft.	3 ft. 0 in. 94 ft.	0 ft. 0 in. 100 ft.
in.	in.	in.	in.	in.	in.	in.	in.
4·26	5·13	7·08	5·88	5·29	6·04	7·83	7·25
1·12	2·41	2·87	1·87	1·50	1·74	1·89	1·80
3·13	4·19	4·13	5·04	4·01	2·46	3·02	2·40
2·33	3·24	3·12	2·77	2·76	1·17	1·14	1·00
4·03	3·70	5·21	4·49	3·42	3·69	3·63	4·20
6·63	8·92	10·52	8·52	7·00	4·87	5·00	5·75
2·36	2·38	3·24	3·84	3·64	1·86	1·68	1·80
5·21	6·32	8·17	9·01	7·89	4·43	5·29	4·68
2·80	3·49	3·12	3·37	3·54	2·78	3·52	3·10
2·01	3·38	3·99	4·90	4·01	2·71	3·86	3·40
3·27	2·46	3·45	3·14	2·64	4·24	3·99	5·25
5·47	9·79 ?	7·42	4·63	4·44	6·97	8·40	8·00
42·62	55·41?	62·32	57·46	50·14	42·96	49·25	48·63

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* Observations discontinued, position being unfavourable.

ENGLAND AND WALES.

Division V.—South-Western Counties (*continued*).						
Cornwall (*continued*).						
1860.	Truro.	Bodmin.	Warleggan, Bodmin.	Pencarrow, Bodmin.	Treharrock House, Wadebridge.	St. Petroc Minor, Padstow.
Height of Rain-gauge above Ground .. / Sea-level.	40 ft. 0 in. 56 ft.	3 ft. 0 in. 300 ft.	3 ft. 0 in. 800 ft.	4 ft. 0 in. 230 ft.	3 ft. 0 in. 200 ft. ?	0 ft. 2 in. 96 ft.
	in.	in.	in.	in.	in.	in.
January	6·91	7·76	7·68	6·68	5·57	5·22
February	1·69	1·73	2·13	2·48	1·49	1·47
March	2·78	4·17	5·20	3·91	3·04	3·59
April...	1·26	1·55	2·09	1·57	1·38	1·08
May	4·04	3·47	5·14	3·02	2·90	3·24
June	7·38	8·49	10·70	7·43	6·03	5·89
July	1·59	2·22	2·98	2·58	2·86	3·04
August	5·78	7·58	9·17	6·98	6·26	5·51
September	3·39	3·60	4·23	4·74	3·91	3·18
October	3·14	3·51	5·08	3·44	3·38	3·80
November	4·26	3·94	4·40	4·93	3·39	4·52
December	7·84	8·31	8·25	3·85	5·93	6·86
Totals	50·06	56·33	67·05	51·61	46·14	47·40

Div. V.—S.-W. Co. (*cont.*).		Division VI.—West Midland Counties.				
Somerset (*continued*).		**Gloucester.**				
1860.	Bath.	Institution, Bristol.	Clifton.	Clifton.	Cirencester.	The Sp Glouc
Height of Rain-gauge above Ground .. / Sea-level.	50 ft. 0 in. 150 ft.	56 ft. 0 in. 98 ft.	0 ft. 6 in. 192 ft.	50 ft. 0 in. 242 ft.	1 ft. 0 in. 446 ft.	3 ft. 6 50 ft. ?
	in.	in.	in.	in.	in.	in.
January	4·60	6·10	4·94	4·27	4·52	3·02
February	1·45	1·41	·99	·74	1·20	·49
March	3·95	3·05	2·92	2·34	2·27	1·99
April	2·48	2·46	1·69	1·32	1·00	·90
May	4·05	3·17	3·54	3·21	3·85	2·69
June	6·63	7·22	7·10	6·44	5·92	4·99
July	2·25	2·34	1·87	1·63	1·75	1·15
August	6·47	6·04	5·68	5·15	5·03	3·74
September	3·08	2·30	2·43	2·22	3·35	2·66
October	3·35	3·39	3·03	2·68	2·00	1·83
November	3·54	2·56	2·83	2·33	3·00	2·31
December	2·82	2·92	3·78	3·19	3·05	2·22
Totals	44·67	42·96	40·80	35·52	36·94	27·99

ENGLAND AND WALES.

Division V.—South-Western Counties (*continued*).

Cornwall (*continued*).	Somerset.						
Rosecarrock, Port Isaac.	Taunton.	Long Sutton.	Bridgewater.	Street.	Frome (North Hill).	Mells, Frome.	Sidcot, Axbridge.
3 ft. 0 in. 180 ft.	1 ft. 3 in. 50 ft.	0 ft. 0 in. 170 ft.?	6 ft. 6 in. 45 ft.	5 ft. 0 in. 70 ft.?	0 ft. 3 in. ………	8 ft. 0 in. 300 ft.	4 ft. 7 in. 250 ft.
in.	in.	in.	in.	in.	in.	in.	in.
5·28	3·22	2·93	1·25	4·67	2·78	4·89	3·81
1·37	·69	·66	1·32	·93	1·45	1·50	1·04
3·05	2·26	1·99	1·32	2·55	2·75	2·84	2·98
1·10	1·82	1·96	2·09	1·80	1·90	2·93	2·48
2·84	2·38	2·10	3·22	3·50	3·12	3·24	4·09
6·10	4·91	6·94	5·65	5·38	7·06	8·65	7·22
2·75	1·60	2·56	2·60	3·11	2·61	2·42	2·76
6·05	3·52	3·91	3·55	4·00	6·45	6·84	7·19
3·30	1·87	1·91	1·30	2·05	2·63	2·67	2·20
3·29	1·70	1·81	1·45	2·42	3·10	4·15	2·86
3·64	4·12	2·66	3·00	2·46	3·00	3·47	2·90
5·56	4·53	2·49	2·78	3·28	2·05	2·97	3·64
44·33	32·62	31·92	29·53	36·15	38·90	46·57	43·17

Division VI.—West Midland Counties (*continued*).

Gloucester (*continued*).		Hereford.	Shropshire.				
County Asylum, Gloucester.	Twigworth, Gloucester.	Rocklands.	Knowbury, Ludlow.	Haughton Hall, Shifnall.	Shrewsbury.	Whittington, Oswestry.	Hengoed, Oswestry.
1 ft. 0 in. 100 ft.	3 ft. 6 in. 50 ft.	……… ………	0 ft. 6 in. 1000 ft.?	4 ft. 6 in. 450 ft.	4 ft. 4 in. 192 ft.	5 ft. 0 in. ………	4 ft. 8 in. ………
in.	in.	in.	in.	in.	in.	in.	in.
3·01	2·74	4·75	3·94	2·61	1·00	4·90	5·90
·45	·57	·66	1·82	·38	2·20	1·02	1·53
2·00	1·92	3·02	1·46	2·12	2·80	2·73	4·59
1·03	1·00	1·37	2·00	·78	·60	1·45	1·62
2·87	2·82	3·27	2·31	2·87	1·00	4·04	4·22
5·34	4·92	7·12	7·04	5·45	1·10	6·51	7·68
·91	·78	1·70	1·97	2·59	1·15	1·88	2·06
3·95	4·18	4·95	5·86	5·78	3·15	4·59	6·16
2·53	2·87	2·85	2·82	1·74	4·10	1·37	1·28
1·63	1·85	2·17	1·63	1·59	1·40	2·85	3·28
2·04	2·37	3·52	1·57	1·63	1·50	2·43	2·60
2·25	2·46	5·39	5·45	3·69	·80?	4·13	4·59
28·01	28·48	40·77	37·87	31·23	20·80?	37·90	45·51

ENGLAND AND WALES.

Division VI.—West Midland Counties (*continued*).

		Stafford.	Worcester.		Warwick.		
1860.		Leek.	Worcester.	Orleton, Tenbury.	Stoneleigh Abbey.	Rugby.	Bloomsbury, Birmingham
Height of Rain-gauge above	Ground..	25 ft. 0 in.	....	0 ft. 9 in.	0 ft. 8 in.	2 ft. 4 in.	4 ft. 6 in.
	Sea-level.	....	....	200 ft.	....	315 ft.	340 ft.
		in	in.	in.	in.	in.	in.
January		4·50	2·79	3·45	2·25	2·56	3·78
February		2·30	·57	·48	1·02	·84	·81
March		4·83	1·92	2·05	2·15	1·89	2·01
April		1·87	1·20	1·31	·58	1·21	1·08
May		4·14	3·94	2·17	3·60	2·96	2·40
June		6·36	9·90	7·25	5·70	5·36	6·26
July		2·62	2·11	1·01	1·95	1·40	1·45
August		4·88	4·70	5·77	4·42	3·16	6·39
September		3·02	2·81	2·53	2·58	2·51	2·44
October		5·18	1·83	2·36	1·88	2·29	1·93
November		3·10	2·36	2·98	2·68	2·01	2·86
December		3·80	4·94	5·53	2·43	1·35	3·75
Totals		46·60	39·07	36·89	31·24	27·54	35·16

Division VII.—North Midland Counties (*continued*).

Lincolnshire (*continued*).

1860.		Grantham.	Boston.	South Kyme, Sleaford.	Coleby, Lincoln.	Lincoln.	Market Rasen
Height of Rain-gauge above	Ground..	0 ft. 0 in.	....	0 ft. 0 in.	....	3 ft. 6 in.	3 ft. 6 in.
	Sea-level.	179 ft.	....	9 ft.	....	26 ft.	100 ft.
		in.	in.	in.	in.	in.	in.
January		2·81	3·00	3·06	1·76	2·46	3·74
February		1·03	1·20	1·50	·51	·85	·91
March		1·76	1·80	2·32	2·09	2·35	2·30
April		·72	·47	·57	·59	·45	·49
May		2·88	3·48	3·11	3·62	3·50	2·51
June		3·58	4·21	4·09	2·77	3·42	4·30
July		3·12	1·60	2·09	1·70	2·14	1·93
August		4·67	5·35	4·09	4·25	4·29	4·49
September		2·88	2·96	3·79	3·14	2·43	2·60
October		1·78	1·92	1·93	1·37	1·48	1·92
November		2·23	2·40	2·44	1·96	1·77	2·29
December		2·21	2·30	2·74	2·62	2·01	1·31
Totals		29·67	30·69	31·73	26·38	27·15	28·79

ENGLAND AND WALES.

Div. VI. (*cont.*).	Division VII.—North Midland Counties.						
WARWICK (*ontinued*).	LEICESTERSHIRE.					RUTLAND.	LINCOLNSHIRE.
Camp Hill, irmingham.	Wigston.	Leicester.	Thornton.	Rothley, Loughborough.	Belvoir Castle.	Empingham.	Wytham-on-the-Hill.
9 ft. 0 in. 416 ft.	0 ft. 6 in.	....	2 ft. 8 in.	0 ft. 4 in. 210 ft. ?	0 ft. 8 in. 237 ft.	4 ft. 0 in.	4 ft. 3 in. ....
in.	in.	in.	in.	in.	in.	in.	in.
3·84	3·10	2·95	2·83	....	2·92	2·35	2·44
·93	·79	·71	·57	....	1·08	·95	3·20
2·06	2·45	2·75	2·10	....	1·67	1·80	
1·18	·93	·91	·83	....	·57	·30	·03
2·42	3·19	2·39	3·21	....	2·76	3·00	3·40
6·44	5·01	3·72	4·32	....	3·54	3·20	4·51
1·51	1·99	6·54	1·71	....	1·54	1·15	1·32
6·48	3·49		4·98	....	5·60	2·81	4·01
2·28	3·21		2·42	2·90	3·54	2·06	2·10
1·97	2·09	2·67	1·64	1·76	2·06	1·70	1·73
2·93	2·80	1·37	2·69	1·90	1·94	2·45	2·57
3·62	2·42	·98	2·36	1·63	2·01	1·75	1·02
35·66	31·47	24·99	29·66	....	29·23	23·52	26·33

Division VII.—North Midland Counties (*continued*).							
LINCOLNSHIRE (*continued*).							NOTTINGHAMSHIRE.
Gainsborough.	Spring Gardens, Gainsboro'.	Stockwith.	Brigg.	Grimsby.	Barnetby.	New Holland.	Highfield House.
3 ft. 6 in. 76 ft.	8 ft. 0 in. 38 ft.	3 ft. 6 in. 21 ft.	3 ft. 6 in. 16 ft.	15 ft. 0 in. 42 ft.	3 ft. 6 in. 51 ft.	3 ft. 6 in. 18 ft.	0 ft. 0 in. 162 ft.
in.	in.	in.	in.	in.	in.	in.	in.
3·04	2·97	3·63	3·55	1·94	3·00	3·18	3·35
·53	·90	·64	1·11	1·48	·84	·82	2·14
2·01	2·46	1·72	2·60	2·09	2·26	2·17	2·26
·46	·66	·71	·79	·74	·88	·84	·60
2·83	3·41	2·96	3·37	2·13	2·35	2·70	3·89
3·19	3·15	2·93	4·40	2·79	4·34	4·66	4·92
2·81	2·87	1·77	1·72	2·55	1·51	1·20	1·51
4·75	4·27	4·28	3·96	2·45	3·52	4·52	6·28
3·60	3·73	2·88	2·14	2·58	2·93	2·35	3·26
1·11	1·25	1·35	1·10	·96	1·45	1·37	2·62
2·56	1·96	2·19	2·52	1·64	2·30	2·71	2·39
2·42	2·12	1·40	2·01	·94	1·66	1·96	2·66
29·31	29·75	26·46	29·27	22·29	27·04	28·48	35·88

ENGLAND AND WALES.

Division VII.—North Midland Counties (*continued*).

Nottinghamshire (*continued*).

1860.		Highfield House.	Welbeck.	Worksop.	Retford.	East Retford.	West Retford.
Height of Rain-gauge above	Ground..	25 ft. 0 in.	4 ft. 0 in.	3 ft. 6 in.	3 ft. 6 in.	3 ft. 0 in.	0 ft. 6 in.
	Sea-level.	187 ft.	………	127 ft.	52 ft.	50 ft.	50 ft.
		in.	in.	in.	in.	in.	in.
January		2·58	3·62	3·29	3·44	3·27	3·14
February		·81	·69	1·54	·53	·60	·76
March		1·99	1·94	1·90	2·07	2·11	2·18
April		·51	·84	·59	·54	·54	·60
May		3·32	3·21	2·78	2·50	2·34	2·28
June		3·25	3·11	3·93	2·10	2·30	2·44
July		1·27	1·89	2·55	2·07	2·09	2·08
August		5·56	5·78	5·53	4·75	4·86	4·64
September		2·80	2·98	2·38	3·86	3·84	3·72
October		2·15	1·86	1·97	1·64	1·58	1·60
November		2·13	2·13	2·48	2·17	2·16	2·17
December		2·34	2·49	1·67	2·46	2·44	2·59
Totals		28·71	30·54	30·61	28·13	28·13	28·20

Division VIII.—North-Western Counties.

Cheshire.

1860.		Bosley Minns.	Bosley, Reservoir.	Macclesfield.	Sponds Hill, Bollington.	Whaley.	Aqueduct, Marple.
Height of Rain-gauge above	Ground..	3 ft. 6 in.	3 ft. 6 in.	3 ft. 6 in.	3 ft. 6 in.	3 ft. 6 in.	3 ft. 6 in.
	Sea-level.	1210 ft.	590 ft.	539 ft.	1279 ft.	602 ft.	321 ft.
		in.	in.	in.	in.	in.	in.
January		2·85	3·03	3·47	4·20	3·97	2·30
February		·50	·65	·81	·49	·39	·69
March		2·30	3·24	4·50	7·92	7·81	5·34
April		·95	1·09	1·41	2·08	1·84	1·18
May		3·34	2·80	3·06	4·56	4·30	4·52
June		5·77	5·12	5·44	6·57	6·98	6·30
July		2·27	2·15	2·56	3·88	3·58	2·39
August		6·93	6·66	6·53	6·07	5·62	5·59
September		2·98	2·50	2·38	2·86	2·65	2·51
October		3·37	2·63	3·33	5·44	5·15	4·76
November		2·60	2·03	2·31	2·64	2·56	2·22
December		2·35	2·13	2·84	1·90	1·99	2·07
Totals		36·21	34·03	38·64	48·61	46·84	39·87

ENGLAND AND WALES.

Division VII.—North Midland Counties (*continued*).							
Derbyshire.							
Derby.	Chatsworth, Gardens.	Chesterfield.	Norwood.	Combs Moss.	Combs Reservoir.	Chapel-en-le-Frith.	Woodhead.
5 ft. 0 in. 179 ft.	6 ft. 0 in. 404 ft.	3 ft. 6 in. 248 ft.	3 ft. 6 in. 238 ft.	3 ft. 6 in. 1669 ft.	3 ft. 6 in. 710 ft.	3 ft. 6 in. 965 ft.	3 ft. 6 in. 939 ft.
in.	in.	in.	in.	in.	in.	in.	in.
2·97	....	4·16	3·59	4·39	5·28	4·34	5·46
·86	....	·64	·63	·93	1·17	1·16	2·89
2·06	....	2·36	1·97	3·96	7·24	5·62	8·28
·76	1·27	·69	·81	1·46	1·87	1·50	3·11
3·70	1·78	3·35	1·99	4·10	4·29	3·70	5·32
5·21	4·69	4·26	3·48	9·23	7·00	6·02	11·22
1·89	·87	1·20	1·85	3·60	3·93	3·39	3·38
6·23	5·68	4·45	3·94	8·88	7·14	6·34	6·72
2·54	2·60	2·05	2·02	3·52	3·27	2·68	3·81
2·52	3·13	1·72	2·05	6·15	6·02	4·93	7·30
1·51	3·05	2·30	2·70	4·01	3·51	2·91	6·01
2·52	2·60	2·36	2·63	2·77	3·45	2·40	2·85
32·77	....	29·54	27·66	53·00	54·17	44·99	66·35

Division VIII.—North-Western Counties (*continued*).							
Cheshire (*continued*).				Lancashire.			
Lock House, Marple Top.	Hill End, Mottram.	Matley's Field, Mottram.	Newton.	Observatory, Liverpool.	Sandfield Park, Liverpool.	Old Trafford, Manchester.	Sale, Manchester.
3 ft. 6 in. 543 ft.	3 ft. 6 in. 680 ft.	3 ft. 6 in. 399 ft.	3 ft. 6 in. 396 ft.	30 ft. 0 in. 52 ft.	2 ft. 0 in.	3 ft. 0 in. 106 ft.	2 ft. 3 in. 134 ft.
in.	in.	in.	in.	in.	in.	in.	in.
2·56	....	2·97	2·35	1·70	3·26	3·58	3·38
·45	....	·48	·60	·50	1·11	·87	·90
3·64	4·52	4·57	3·50	1·86	2·98	3·47	3·09
·89	1·53	1·34	1·29	·77	·71	1·31	1·05
3·03	3·99	3·99	2·41	1·88	2·78	2·69	2·53
4·94	7·61	6·47	6·79	3·13	5·38	6·04	6·46
1·60	2·99	2·78	2·16	1·54	1·80	1·66	2·02
4·05	5·29	5·12	4·48	6·03	6·50	5·17	5·45
1·56	2·71	2·76	2·18	1·77	2·17	2·88	2·42
3·58	4·50	4·26	4·07	2·44	3·82	3·43	3·34
1·42	2·67	2·39	2·51	1·18	1·95	2·11	2·38
1·56	1·69	1·80	1·60	1·73	2·94	2·93	3·22
29·28	....	38·93	33·94	24·53	35·40	36·14	36·24

ENGLAND AND WALES.

Division VIII.—North-Western Counties (*continued*).

Lancashire (*continued*).

1860.		Market-st., Manchester.	Piccadilly, Manchester.	Fairfield.	Waterhouses, Oldham.	The Folds, Bolton-le-Moors.	Belmont. Bolton.
Height of Rain-gauge above	Ground ..	3 ft. 0 in.	46 ft. 0 in.	6 ft. 0 in.	3 ft. 6 in.	2 ft. 0 in.	0 ft. 0 in.
	Sea-level.	....	194 ft.	312 ft.	345 ft.	290 ft.	800 ft.
		in.	in.	in.	in.	in.	in.
January		3·12	3·61	3·59	3·59	5·57	5·70
February		·94	·81	1·01	1·31	1·64	1·50
March		3·24	3·79	5·24	5·26	5·81	4·60
April...		1·24	1·46	1·38	1·47	1·75	2·40
May		2·93	3·36	3·39	3·53	5·14	4·70
June		6·59	7·49	5·96	5·79	8·74	9·20
July		1·66	1·91	2·30	2·21	2·16	2·10
August		5·33	5·71	5·64	5·66	6·98	9·90
September		1·78	3·17	2·91	2·70	3·93	4·00
October		3·95	4·26	4·66	5·14	7·52	7·60
November		2·24	2·56	3·05	2·76	3·99	4·00
December		2·93	3·27	2·97	3·01	4·43	4·10
Totals		35·95	41·40	42·10	42·43	57·66	59·80

Division VIII.—North-Western Counties (*continued*).

Lancashire (*continued*).

							Div. IX. Yorkshire.
							W. Rid
1860.		Bleasdale, Garstang.	Caton, Lancaster.	Holker, Cartmel.	Wray Castle, Windermere.	Coniston Park.	Station, Sheffield.
Height of Rain-gauge above	Ground ..	4 ft. 6 in.	2 ft. 4 in.	4 ft. 8 in.	4 ft. 9 in.	4 ft. 11 in.	3 ft. 6 in.
	Sea-level.	600 ft.	120 ft.	155 ft.	250 ft.	154 ft.	188 ft.
		in.	in.	in.	in.	in.	in.
January		....	5·86	5·97	10·87	15·60	3·43
February		....	1·43	3·29	3·98	5·50	·62
March		....	4·19	5·03	8·12	10·50	1·60
April		....	1·37	1·45	2·24	2·00	·69
May		3·61	2·26	2·53	4·34	4·70	2·17
June		9·43	7·32	5·24	7·28	9·70	4·12
July		·92	1·07	1·11	1·89	2·00	1·97
August		6·84	7·87	6·19	7·69	11·50	3·77
September		2·94	2·90	1·89	2·30	2·50	2·09
October		4·35	6·24	7·17	11·79	13·50	2·39
November		1·10	2·37	2·64	3·81	4·00	2·40
December		2·88	3·94	4·56	5·14	8·00	2·33
Totals		....	46·82	47·07	69·45	89·50	27·58

ENGLAND AND WALES.

Division VIII.—NORTH-WESTERN COUNTIES (*continued*).

LANCASHIRE (*continued*).

Heaton, Bolton.	Standish, Wigan.	Howick, Preston.	Fishwick, Preston.	House of Correction, Preston.	House of Correction, Preston.	South Shore, Blackpool.	Observatory, Stonyhurst.
0 ft. 0 in. 500 ft.	0 ft. 0 in. 285 ft.	0 ft. 6 in. 72 ft.	24 ft. 0 in. 154 ft.	1 ft. 1 in. 140 ft.	53 ft. 6 in. 187 ft.	1 ft. 8 in. 29 ft.	0 ft. 0 in. 381 ft.
in.	in.	in.	in.	in.	in.	in.	in.
4·00	4·14	4·53	3·52	4·04	3·50	3·85	4·70
1·30	1·33	1·05	·96	1·00	·78	1·40	1·80
3·20	4·78	3·61	3·32	3·58	2·91	2·90	6·10
1·60	1·09	1·37	1·04	1·14	·93	1·00	1·70
3·70	4·42	3·00	3·16	3·43	3·10	1·50	4·20
7·50	6·78	5·06	4·32	5·09	4·46	3·65	6·40
1·90	2·49	1·33	1·92	1·49	1·42	1·25	1·80
6·70	7·10	5·67	5·48	5·69	5·48	5·30	6·40
3·20	2·90	2·24	3·20	2·19	1·94	2·10	3·50
5·10	4·96	4·86	5·20	5·30	4·33	4·20	7·70
2·90	3·29	3·19	2·32	2·39	2·10	1·70	2·80
3·80	2·76	3·85	1·60	2·52	2·33	2·85	3·50
44·90	46·04	39·76	36·04	37·86	33·28	31·70	50·60

Division IX.—YORKSHIRE (*continued*).

YORKSHIRE—WEST RIDING (*continued*).

The Edge, Sheffield.	Broomhall Park, Sheffield.	Redmires, Sheffield.	Tickhill.	Dunford Bridge.	Penistone.	Carlcotes.	Standedge.
3 ft. 6 in. 336 ft.	0 ft. 4 in. 337 ft.	3 ft. 0 in. 1100 ft.	0 ft. 1 in. 61 ft.	3 ft. 6 in. 954 ft.	3 ft. 6 in. 717 ft.	3 ft. 6 in. 1075 ft.	2 ft. 0 in. 1150 ft.
in.	in.	in.	in.	in.	in.	in.	in.
....	4·85	4·51	3·67	5·16	4·21	....	5·50
....	1·31	1·69	·63	2·38	1·86	....	1·50
2·66	2·53	4·88	1·77	7·52	3·30	....	6·50
1·28	1·25	1·57	·93	2·28	1·39	2·09	2·50
2·97	2·91	3·25	2·09	4·57	2·83	3·59	3·50
4·28	4·49	5·49	3·32	10·13	4·05	7·88	9·50
1·80	1·77	2·04	2·73	3·26	1·62	2·69	2·50
4·89	4·91	6·13	5·24	7·13	3·75	6·05	6·75
2·67	2·50	3·11	4·18	3·43	1·27	2·78	4·75
3·11	3·07	4·51	2·01	7·13	2·15	6·12	8·00
2·86	3·13	3·66	2·60	5·63	1·84	3·40	3·75
3·48	4·47	3·44	2·16	4·17	1·84	2·48	2·00
....	37·19	44·28	31·33	62·79	30·11	....	56·75

ENGLAND AND WALES.

Division IX.—Yorkshire (*continued*).

Yorkshire—West Riding (*continued*).

1860.	Saddleworth.	Ackworth Villa.	Longwood, Huddersfield.	Wakefield.	Rastrick, Huddersfield.	Well Head, Halifax.
Height of Rain-gauge above Ground ..	5 ft. 0 in.	0 ft. 1 in.	24 ft. 0 in.	4 ft. 0 in.	2 ft. 0 in.	1 ft. 0 in.
Height of Rain-gauge above Sea-level.	640 ft.	135 ft.	....	115 ft.	410 ft.	487 ft.
	in.	in.	in.	in.	in.	in.
January	4·46	3·86	3·23	3·50	3·92	3·97
February	1·04	·93	1·01	·90	1·28	1·60
March	4·61	2·21	3·37	2·06	2·83	3·26
April	1·76	·69	1·65	·72	1·19	1·22
May	3·16	4·60	2·38	2·98	2·48	3·16
June	8·28	4·06	5·82	4·81	4·94	4·98
July	2·87	1·86	1·69	3·54	1·50	1·47
August	5·77	4·00	3·84	4·09	3·98	3·77
September	3·45	2·96	3·18	2·26	2·22	1·98
October	5·44	1·92	3·98	1·65	3·27	3·63
November	3·98	2·55	3·25	3·28	3·25	3·35
December	2·17	3·42	1·34	3·69	2·51	1·94
Totals	46·59	33·06	34·74	33·48	33·37	34·33

Division IX.—Yorkshire (*continued*).

Yorkshire—West Riding (*continued*).

1860.	Red Hall, Whinmoor.	Eccup, Leeds.	Ben Rhydding, Otley.	Settle.	Clapham.	Arncliffe.
Height of Rain-gauge above Ground ..	5 ft. 0 in.	0 ft. 0 in.	2 ft. 6 in.	40 ft. 0 in.	5 ft. 0 in.	2 ft. 6 in.
Height of Rain-gauge above Sea-level.	455 ft.	340 ft.	500 ft.	498 ft.	550 ft.	750 ft.
	in.	in.	in.	in.	in.	in.
January	3·84	3·28	3·70	6·96	4·79	6·29
February	1·07	1·35	·70	1·98	1·61	2·54
March	1·88	1·98	3·00	3·70	4·46	4·94
April	1·11	·96	1·30	1·22	2·06	3·05
May	2·97	2·75	3·50	3·37	2·59	3·28
June	5·22	4·45	5·90	4·30	5·32	6·66
July	3·49	3·15	2·40	1·16	1·53	1·89
August	4·90	3·90	1·90	5·33	6·11	8·73
September	3·10	1·81	2·00	1·95	2·20	2·46
October	1·83	1·93	3·20	4·98	4·90	7·67
November	2·99	2·79	3·30	3·58	2·97	4·33
December	3·45	2·65	3·40	3·25	3·10	3·09
Totals	35·85	31·00	34·30	41·78	41·64	54·93

ENGLAND AND WALES.

Division IX.—YORKSHIRE (*continued*).

YORKSHIRE—WEST RIDING (*continued*).

Hunter's Hill, Halifax.	Warley Moor, Halifax.	Midgeley Moor, Halifax.	Ovenden Moor, Halifax.	Horton Hall, Bradford.	Holbeck, Leeds.	Holbeck, Leeds.	Philosophical Hall, Leeds.
1 ft. 0 in. 1250 ft.	1 ft. 0 in. 1425 ft.	1 ft. 0 in. 1350 ft.	1 ft. 0 in. 1375 ft.	0 ft. 8 in. 496 ft.	40 ft. 0 in. 135 ft.	0 ft. 0 in. 95 ft.	40 ft. 0 in. 137 ft.
in.	in.	in.	in.	in.	in.	in.	in.
4·00	4·60	4·70	4·70	2·68	3·10	3·06	2·98
2·50	3·10	3·00	3·10	·83	1·50	·97	·50
3·80	4·30	4·50	4·70	2·63	2·20	1·70	1·39
3·10	4·00	4·00	3·90	1·44	·50	1·05	·75
4·60	5·10	5·20	5·00	3·22	2·40	2·33	2·81
6·30	7·20	7·20	7·20	6·85	4·70	4·96	4·43
1·80	2·40	2·30	2·90	2·79	2·15	2·11	2·59
4·80	5·90	6·70	6·00	4·71	3·75	3·39	3·95
2·00	2·40	2·60	2·60	2·53	2·00	2·02	2·27
4·90	5·70	6·00	5·80	3·20	1·20	1·48	1·48
2·90	4·50	4·90	4·10	4·05	2·60	2·48	3·25
1·60	2·00	2·00	1·90	3·54	2·50	1·64	1·91
42·30	51·20	53·10	51·90	38·47	28·60	27·19	28·31

Division IX.—YORKSHIRE (*continued*).

YORKSHIRE—EAST RIDING.

Patrington.	Holme-on-Spalding-Moor.	Hull.	Hull.	Wheldrake.	Middleton, Beverley.	York.	Huggate, Pocklington.
4 ft. 8 in. 32 ft.	7 ft. 6 in. 32 ft.	4 ft. 0 in. 12 ft.	27 ft. 0 in. 30 ft.	1 ft. 4 in. 40 ft.	1 ft. 0 in. 150 ft.	0 ft. 5 in. 50 ft.	0 ft. 6 in. 550 ft.
in.	in.	in.	in.	in.	in.	in.	
2·78	3·30	3·09	3·44	3·09	2·90	2·17	Gauge visited October 27th, 1862, and its position found most objectionable, returns therefore omitted.—G. J. S.
1·28	·88	1·07	·93	·49	1·90	1·99	
1·92	2·24	2·01	2·31	2·32	2·85	2·23	
·68	·83	·95	·68	1·25	1·12	1·17	
2·74	2·66	2·63	2·03	3·00	4·05	3·27	
3·54	4·72	4·32	4·46	3·67	4·18	3·32	
3·50	1·95	1·66	1·29	2·48	2·70	2·87	
3·20	4·15	4·98	5·68	3·94	4·00	3·73	
2·20	2·64	3·16	3·05	2·80	2·79	2·88	
1·38	2·08	1·64	1·33	1·90	2·50	1·46	
2·70	3·06	3·08	2·69	2·49	3·69	2·07	
2·56	3·19	3·15	2·84	2·87	4·10	3·21	
28·58	31·70	31·74	30·73	30·30	36·78	30·37	

ENGLAND AND WALES.

	Division IX.—Yorkshire (*continued*).			Div. X.—Northern Countie		
	Yorkshire—North Riding.			Durham.		
1860.	Malton.	Scarborough.	Redcar.	Darlington.	Stubb House, Winston.	Washingt
Height of Rain-gauge above Ground..	1 ft. 0 in.	9 ft. 0 in.	2 ft. 3 in.	4 ft. 0 in.	0 ft. 9 in.	20 ft. 0 in.
Height of Rain-gauge above Sea-level.	80 ft.	91 ft.	20 ft.	140 ft.	460 ft.	120 ft.
	in.	in.	in.	in.	in.	in.
January	3·31	1·36	1·52	2·55	1·74	3·24
February	1·45	1·11	·92	1·99	·86	1·26
March	2·91	1·96	1·30	2·39	2·59	1·02
April	1·12	·35	·73	·77	1·16	·85
May	4·01	2·80	1·51	4·25	1·81	2·20
June	4·42	1·82	1·92	2·82	5·78	3·86
July	2·56	1·95	2·05	3·76	2·07	2·94
August	3·30	1·11	2·07	3·61	3·78	2·33
September	2·64	3·69	1·45	1·19	1·35	1·87
October	1·82	1·94	1·50	2·00	2·07	1·80
November	3·30	2·97	2·41	2·08	2·87	2·70
December	3·62	2·94	2·25	4·50	4·20	3·54
Totals	34·46	24·00	19·63	31·91	30·28	27·61

	Division X.—Northern Counties (*continued*).					
	Northumberland (*continued*).					Cumber-land.
1860.	Wylam.	N. Shields.	Stamford-ham.	High House, Alnwick.	Lilburn Tower, Alnwick.	The Fl Cleat
Height of Rain-gauge above Ground..	0 ft. 4 in.	1 ft. 0 in.	1 ft. 1 in.	0 ft. 6 in.	6 ft. 0 in.	1 ft. 6 in.
Height of Rain-gauge above Sea-level.	96 ft.	124 ft.	380 ft.	400 ft.	250 ft. ?	240 ft.
	in.	in.	in.	in.	in.	in.
January	4·10	3·45	4·28	4·50	4·07	7·67
February	1·77	1·53	2·08	1·80	2·18	2·65
March	2·19	1·93	2·12	2·10	2·53	5·03
April	·97	1·13	1·24	1·20	1·05	2·53
May	2·21	3·20	1·51	2·10	·28	3·66
June	3·58	2·66	5·06	3·10	3·93	6·69
July	2·71	2·95	3·81	2·70	3·19	2·23
August	2·13	2·84	2·40	3·00	3·56	6·65
September	1·11	1·88	1·30	1·70	1·91	2·03
October	3·02	2·24	2·93	2·90	2·72	9·12
November	3·06	3·40	4·44	5·60	5·01	2·02
December	4·53	4·98	4·09	5·90	3·78	5·61
Totals	31·38	32·19	35·26	36·60	34·21	55·89

ENGLAND AND WALES.

Division X.—Northern Counties (*continued*).

Durham (*continued*).			Northumberland.				
Durham.	Bishop-wearmouth.	Sunderland.	Shotley Hall.	Allenheads.	Allenheads.	Newcastle.	Bywell.
1 ft. 0 in. 338 ft.	30 ft. 0 in. 140 ft.	1 ft. 6 in. 130 ft.	0 ft. 8 in. 309 ft.	0 ft. 5 in. 1360 ft.	6 ft. 9 in. 1367 ft.	42 ft. 0 in. 187 ft.	0 ft. 6 in. 87 ft.
in.	in.	in.	in.	in.	in.	in.	in.
3·31	2·81	3·66	2·36	9·91	8·43	3·59	4·55
1·46	1·12	1·29	2·51	5·19	5·25	1·04	2·15
1·66	1·35	1·13	2·94	4·99	5·34	1·25	2·88
·62	·87	·94	1·17	3·11	3·33	·98	1·62
2·33	1·97	2·37	1·24	3·17	2·92	2·30	2·44
3·97	2·55	2·87	4·92	6·26	6·62	3·10	4·59
3·17	2·94	3·05	3·94	3·20	3·00	2·67	3·54
2·73	2·24	2·05	3·19	4·93	5·06	2·39	3·03
1·61	2·44	2·26	1·37	1·87	1·65	1·09	1·54
1·92	1·50	2·12	2·42	6·24	7·55	2·31	3·52
2·79	2·44	3·05	4·21	4·76	4·91	2·88	3·27
4·76	2·48	4·60	5·08	5·52	5·85	3·68	5·00
30·33	24·71	29·39	35·35	59·15	59·91	27·28	38·13

Division X.—Northern Counties (*continued*).

Cumberland (*continued*).					Westmoreland.		
Seathwaite, Borrowdale.	Keswick.	Mirehouse, Bassenthwaite.	Silloth.	O. S. Office, Carlisle.	Kendal.	Lesketh How, Ambleside.	The How, Troutbeck.
1 ft. 0 in. 422 ft.	6 ft. 3 in. 270 ft.	0 ft. 5 in. 300 ft.	6 ft. 0 in. 16 ft.	47 ft. 0 in. 105 ft.	4 ft. 6 in. 149 ft.	3 ft. 0 in. 200 ft.	1 ft. 8 in. 403 ft.
in.	in.	in.	in.	in.	in.	in.	in.
23·79	11·14	8·25	5·79	5·55	8·71	14·34	17·79
9·23	3·22	2·51	1·90	1·46	2·60	5·55	5·52
17·15	6·51	6·47	3·64	2·93	5·80	8·56	10·43
5·04	1·75	2·23	1·51	1·54	2·09	3·14	4·92
9·80	3·57	2·84	2·40	1·82	2·72	5·33	6·31
15·87	4·33	4·92	3·78	3·09	7·79	7·78	11·90
3·21	2·28	1·86	2·29	2·49	2·47	2·00	2·13
13·91	5·68	5·82	4·37	3·29	6·20	6·47	7·96
6·68	1·32	1·65	1·29	1·44	3·71	3·01	3·02
23·70	8·52	8·57	6·85	4·89	8·06	15·46	18·32
4·76	2·11	1·99	1·84	1·12	3·10	3·27	5·13
9·06	3·74	2·68	2·15	2·00	3·75	5·06	9·15
142·20	54·17	49·79	37·81	31·62	57·00	79·97	102·58

ENGLAND AND WALES.

Division X.—Northern Counties (*continued*).				Div. XI.—Monmouthshire, Wales, and the Isles.		
Westmoreland (*continued*).				Glamorgan	Pembroke.	Cardigan.
1860.	Lancregg, Grasmere.	Lowther Castle.	Brougham Hall.	Ystalyfera, Swansea.	Haverford-west.	Lampeter.
Height of Rain-gauge above Ground..	4 ft. 6 in.	4 ft. 6 in.	4 ft. 6 in. ?	4 ft. 0 in.	2 ft. 0 in.	5 ft. 0 in.
Sea-level.	300 ft. ?	....	....	300 ft.	60 ft.	425 ft.
	in.	in.	in.	in.	in.	in.
January	19·34	7·03	5·60	8·12	8·27	6·60
February	7·02	2·27	1·10	2·99	3·06	2·00
March	11·98	4·51	4·40	5·24	4·77	5·30
April	1·93	1·66	2·23	2·09	1·71	2·50
May	5·32	2·57	2·40	5·52	3·32	2·70
June	9·76	6·39	4·72	11·23	6·70	7·50
July	2·53	2·64	1·16	3·63	2·36	4·00
August	8·75	5·09	4·25	12·31	8·76	8·60
September	3·80	1·25	·72	5·89	3·21	3·40
October	17·36	6·20	4·57	6·93	5·30	4·60
November	5·31	2·18	2·17	4·79	3·03	3·30
December	11·77	3·54	3·36	4·47	6·50	4·80
Totals	104·87	45·33	36·68	73·21	56·99	55·30

SCOTLAND.

Division XII.—Southern Counties (*continued*).					Div. XIII.—South-Eastern Counties.	
Dumfries.					Selkirk.	Peebles.
1860.	Dumfries.	Drumlanrig.	Wanlock-head.	Wanlock-head.	Bowhill.	Stobo Cast
Height of Rain-gauge above Ground..	0 ft. 5 in.	....	0 ft. 6 in.	0 ft. 4 in.	11 ft. 0 in.	0 ft. 2 in.
Sea-level.	63 ft.	186 ft. ?	1400 ft.	1330 ft.	537 ft.	600 ft.
	in.	in.	in.	in.	in.	in.
January	7·60	9·00	10·70	11·71	4·33	....
February	2·25	3·80	8·25	5·40	2·76	....
March	4·05	5·09	8·00	7·35	3·33	....
April	1·50	·90	2·05	1·67	1·15	....
May	2·00	2·50	3·85	4·59	2·50	....
June	4·15	5·50	7·80	6·83	5·50	3·50
July	1·80	1·90	1·90	3·42	1·36	·50
August	4·45	6·10	6·45	4·31	2·36	3·80
September	1·05	1·00	3·10	3·12	1·07	·50
October	6·60	6·80	12·15	9·09	2·16	3·00
November	2·00	....	3·60	3·49	2·54	1·10
December	4·30	4·60	4·85	4·33	3·48	1·60
Totals	41·75	....	72·70	65·31	32·54	....

ENGLAND AND WALES. SCOTLAND.

Division XI.—MONMOUTHSHIRE, WALES, AND THE ISLES (*cont.*).						Division XII. SOUTHERN COUNTIES.	
ANGLESEY.	CARNARVON.	FLINT.	ISLANDS.			WIGTOWN.	KIRKCUDBRIGHT.
Llandyfrydog.	Llandudno.	Hawarden.	Guernsey.	St. Mary's, Scilly.	Ballasalla, Isle of Man.	South Cairn, Stranraer.	Cargen.
2 ft. 0 in. 92 ft.	0 ft. 4 in. 20 ft. ?	0 ft. 0 in. 260 ft.	12 ft. 0 in. 200 ft.	1 ft. 0 in. 30 ft.	0 ft. 2 in. 100 ft.	0 ft. 4 in. 210 ft.	0 ft. 3 in. 80 ft.
in.	in.	in.	in.	in.	in.	in.	in.
....	2·10	2·45	6·60	4·10	6·19	7·05	6·93
....	·50	·50	2·10	1·80	1·88	2·45	1·83
....	1·60	2·45	2·20	2·36	3·03	3·85	3·67
....	·90	·90	2·50	·87	2·43	1·75	1·15
2·05	2·00	1·95	4·00	1·68	2·15	3·25	2·02
4·15	3·50	4·16	5·00	3·28	4·97	5·60	5·43
1·38	1·50	1·38	1·70	·81	1·09	1·10	2·46
6·34	6·70	4·95	6·00	3·53	4·31	4·25	4·90
3·42	2·70	1·40	3·80	1·77	1·14	1·80	1·26
5·99	4·30	2·00	3·30	2·54	5·95	4·65	6·59
2·39	1·80	1·96	4·20	3·99	2·04	2·90	2·45
3·10	2·40	3·70	6·60	6·47	1·99	3·65	5·58
....	30·00	27·80	48·00	33·20	37·17	42·30	44·27

SCOTLAND.

Division XIII.—SOUTH-EASTERN COUNTIES (*continued*).							
BERWICK.		HADDINGTON.				EDINBURGH.	
Milne Graden.	Mungo's Walls, Dunse.	Yester.	Smeaton.	East Linton.	Thurston, Dunbar.	Harlaw, Edinburgh.	North Esk Reservoir.
.... 300 ft. ?	0 ft. 4 in. 267 ft.	0 ft. 6 in. 420 ft. ?	13 ft. 6 in. 100 ft.	0 ft. 3 in. 90 ft.	3 ft. 0 in. 320 ft.	0 ft. 6 in. 770 ft.	0 ft. 6 in. 1150 ft.
in.	in.	in.	in.	in.	in.	in.	in.
4·70	5·30	4·20	3·02	3·71	5·10	6·30	4·90
1·20	·80	1·65	·71	·79	·10	2·30	6·40
2·10	1·39	2·20	1·16	1·51	3·30	3·00	4·95
·90	·64	1·60	·68	·83	·20	·80	·78
1·90	1·33	·85	·69	·73	1·70	1·40	1·51
5·60	4·01	4·27	3·34	3·44	4·30	4·50	3·95
4·50	2·13	2·80	·50	·70	·40	2·00	2·39
2·00	1·69	2·60	1·50	2·01	2·20	4·00	3·09
1·60	·85	3·56	·92	1·16	1·40	1·10	·95
2·40	2·57	2·90	2·31	2·43	5·20	4·50	4·98
2·80	3·60	2·99	2·50	3·10	6·30	3·70	1·51
2·10	5·56	4·78	4·12	6·20	3·90	4·50	3·65
31·80	29·87	34·40	21·45	26·61	34·10	38·10	39·06

SCOTLAND.

Division XIII.—SOUTH-EASTERN COUNTIES (*continued*).						Div. XIV. S.-W. C
EDINBURGH (*continued*).						LANARK.
1860.	Glencorse.	Fernielaw.	Inveresk, Musselburgh.	Edinburgh.	Edinburgh.	Auchinraith.
Height of Rain-gauge above: Ground.. / Sea-level.	0 ft. 6 in. 680 ft.	0 ft. 6 in. 500 ft.	3 ft. 0 in. 60 ft.	7 ft. 0 in. 200 ft.	78 ft. 0 in. 363 ft.	4 ft. 9 in. 150 ft.
	in.	in.	in.	in.	in.	in.
January ..	4·80	5·50	4·21	3·63	1·77	4·00?
February	2·85	2·30	2·34	....	·79	2·94
March	3·50	2·70	2·60	....	·66	2·75
April	·85	·60	·78	·40	·40	·98?
May	1·05	1·25	1·85	2·16	1·09	1·73
June	3·90	4·05	4·37	3·53	2·45	3·51
July	1·25	1·45	1·30	1·13	·97	2·70
August	1·90	2·60	2·67	2·27	1·65	3·10
September	1·05	1·00	·98	·76	·34	1·02
October	3·45	3·80	3·17	2·65	1·49	4·15
November	2·10	3·20	2·18	2·68	1·53	1·45
December	3·00	4·30	5·52	1·90	1·25	2·25?
Totals	29·70	32·75	31·97	....	14·39	30·58?

Division XIV.—SOUTH-WESTERN COUNTIES (*continued*).					Div. XV.—WEST MIDLAND COUNTIES.	
RENFREW.					STIRLING.	
1860.	Nither Place, Mearns.	Kilbarchan.	Ferguslie House, Paisley.	Greenock.	Stirling.	Polmais Gard
Height of Rain-gauge above: Ground.. / Sea-level.	1 ft. 2 in. 350 ft.	1 ft. 0 in. 350 ft.	0 ft. 3 in. 85 ft.	0 ft. 6 in. 64 ft.	.... 233 ft.?	0 ft. 2 in. 8 ft.
	in.	in.	in.	in.	in.	in.
January	8·90	8·10	7·12	7·90	4·55	3·60
February	5·40	7·10	6·10	7·00	2·13	6·00
March	4·50	6·90	4·61	7·20	3·26	4·20
April	1·00	1·90	1·30	2·05	1·10	1·00
May	2·50	3·45	1·90	3·95	1·42	1·00
June	4·00	5·85	3·55	5·75	4·56	4·40
July	2·30	2·45	1·35	1·50	1·64	4·50
August	3·25	5·35	4·20	5·60	4·60	6·50
September	1·50	2·52	1·75	3·45	1·14	1·20
October	5·50	8·10	6·10	7·30	5·14	4·20
November	2·25	3·10	1·50	3·30	1·54	3·00
December	2·30	3·75	3·10	4·25	3·49	3·00
Totals	43·40	58·57	42·48	59·25	34·57	42·60

SCOTLAND.

Division XIV.—South-Western Counties (*continued*).

Lanark (*continued*).					Ayr.		
Bothwell Castle.	Baillieston.	Hillend House, Shotts.	Observatory, Glasgow.	O. S. Office, Glasgow.	Auchendrane House, Ayr.	Largs.	Brisbane Glen.
[illegible] ft. 0 in. 2[illegible]0 ft.	0 ft. 3 in. 230 ft.	7 ft. 0 in. 620 ft.	0 ft. 0 in. 200 ft.	56 ft. 0 in. 160 ft.	2 ft. 3 in. 94 ft.	0 ft. 6 in. 30 ft.?	0 ft. 0 in. 125 ft.
in.	in.	in.	in.	in.	in.	in.	in.
3·67	4·19	3·38	3·60	3·42	6·43	4·90	6·70
2·14	2·53	2·10	2·18	2·50	3·80	4·10	4·15
2·44	2·84	2·80	4·33	2·84	4·30	4·60	4·75
·90	1·36	1·06	1·18	·80	1·62	1·90	2·00
1·72	2·27	2·31	2·17	1·57	3·08	2·90	3·00
3·00	4·23	4·02	5·73	3·85	4·58	4·10	4·45
2·24	1·64	1·28	1·83	1·49	1·72	2·30	2·20
2·12	3·60	3·27	4·47	3·34	3·95	4·40	5·35
·56	1·22	1·17	1·19	1·01	1·75	2·50	2·75
3·80	4·81	5·17	4·59	3·38	6·74	5·50	5·80
1·41	1·83	1·96	2·20	1·23	1·64	4·50	3·50
2·02	2·48	1·97	2·29	3·44	2·32	2·90	3·80
26·02	33·00	30·49	35·76	28·87	41·93	44·60	48·45

Division XV.—West Midland Counties (*continued*).

Bute.		Argyll.					
Isle of Cumbrae.	Rothesay.	Castle Toward.	Hafton Dunoon.	Otter House.	Kilmory, Lochgilphead.	Callton Mor.	The Castle, Inverary.
4 ft. 6 in. 50 ft.	10 ft. 0 in. 40 ft.	4 ft. 0 in. 80 ft.?	4 ft. 0 in. 40 ft.	0 ft. 6 in. 130 ft.	4 ft. 6 in. 100 ft.?	4 ft. 6 in. 65 ft.	0 ft. 0 in. 30 ft.
in.	in.	in.	in.	in.	in.	in.	in.
5·80	5·70	5·68	6·61	5·75	7·96	4·50	6·20
3·80	4·60	3·83	6·99	3·40	4·35	2·75	6·00
3·90	5·60	5·21	8·18	4·20	6·87	4·73	7·10
2·10	2·00	1·74	2·50	2·35	2·56	2·47	5·20
2·80	3·50	3·66	4·17	4·28	4·09	4·10	6·00
3·60	4·70	4·61	5·18	4·10	3·94	4·15	2·20
2·10	2·20	1·68	2·96	1·21	2·83	1·47	6·30
4·40	5·30	5·62	5·94	6·50	6·94	6·41	3·10
1·40	2·50	2·83	4·04	2·26	1·81	3·18	7·00
5·40	5·70	6·65	10·56	7·10	7·71	7·15	12·20
2·20	3·20	2·98	2·23	2·63	2·54	3·09	2·10
3·20	3·20	2·69	2·47	3·98	2·12	1·85	3·00
40·70	48·20	47·18	61·83	47·76	53·72	45·85	66·40

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SCOTLAND.

Division XV.—West Midland Counties (*continued*).				Division XVI.—East Midland Counties.		
Argyll (*continued*).				Kinross.	Fife.	
1860.	Isle of Easdale.	Oban.	Torosay, Isle of Mull.	Loch Leven.	Balfour.	Nookton Leven.
Height of Rain-gauge above Ground..	0 ft. 6 in.	0 ft. 0 in.	1 ft. 0 in.	....	0 ft. 4 in.	0 ft. 6 in.
Height of Rain-gauge above Sea-level.	25 ft.	10 ft.	18 ft.	....	127 ft.	80 ft.
	in.	in.	in.	in.	in.	in.
January	4·90	4·90	4·00	3·70	2·20	4·14
February	5·10	4·60	9·20	1·50	1·30	1·10
March................	5·70	6·20	9·80	3·40	2·60	2·30
April	2·50	2·65	3·60	·60	2·40	·93
May	4·70	5·50	7·70	1·30	1·90	·74
June	4·40	5·50	5·60	5·60	1·40	4·59
July	1·80	2·15	2·30	2·30	·18	1·17
August	3·10	4·40	5·10	3·50	4·00	2·64
September	3·00	4·00	4·70	1·30	1·90	·87
October	9·30	11·05	13·80	4·30	4·90	3·08
November	1·60	1·85	1·80	3·60	3·00	4·23
December	1·80	1·80	2·10	5·00	2·40	4·86
Totals	47·90	54·60	69·70	36·10	28·18	30·65

Division XVI.—East Midland Counties (*continued*).						
Perth (*continued*).						
1860.	Between Glen Finlas and Ben Ledi.	Glengyle.	Auchterarder House.	Stronvar, Loch Earn Head.	Colquhalzie House.	Trinity Gas
Height of Rain-gauge above Ground..	0 ft. 6 in.	0 ft. 6 in.	0 ft. 0 in.	0 ft. 3 in.	0 ft. 5 in.	0 ft. 1 in.
Height of Rain-gauge above Sea-level.	1800 ft.	380 ft.	150 ft.	460 ft.	60 ft. ?	135 ft.
	in.	in.	in.	in.	in.	in.
January	6·20	10·50	4·74	8·05	4·00	4·70
February	2·40	14·50	·65	6·45	3·20	1·90
March................	1·10	11·20	2·19	10·35	3·75	2·70
April	3·10	2·80	·39	2·65	·35	·20
May	3·20	6·20	1·43	5·45	1·60	1·30
June	8·50	9·40	3·69	9·55	5·10	4·50
July	5·70	2·10	2·49	2·80	2·85	2·70
August	6·20	7·50	2·74	6·70	3·50	3·20
September	2·30	5·80	1·33	3·95	1·00	·90
October	5·70	14·10	2·98	11·06	4·30	3·30
November	2·70	4·30	2·89	4·38	4·30	4·15
December	6·70	5·80	3·18	4·25	3·90	4·00
Totals	53·80	95·20	28·70	75·64	37·85	33·55

SCOTLAND.

Division XVI.—East Midland Counties (*continued*).

Fife (*continued*).	Perth.						
Pittenweem.	Aberfoyle.	Ledard.	Kippenross, Dunblane.	Deanston.	Ben Lomond.	Bridge of Turk.	Lanrick Castle.
3 ft. 0 in. 75 ft.	0 ft. 6 in. 60 ft.	0 ft. 6 in. 1500 ft.	0 ft. 4 in. 100 ft.	0 ft. 0 in. 120 ft. ?	0 ft. 6 in. 1800 ft.	0 ft. 6 in. 270 ft.	0 ft. 0 in. 150 ft. ?
in.	in.	in.	in.	in.	in.	in.	in.
3·93	5·20	3·40	3·60	3·70	9·50	8·50	4·00
1·08	1·80	2·10	2·00	2·95	0·00	4·10	5·10
2·48	4·40	1·50	3·00	3·90	12·70	6·20	4·80
·87	·20	2·00	·60	·65	2·00	1·90	·70
·95	3·40	5·50	1·55	3·15	8·00	3·70	3·30
3·85	6·80	14·00	4·35	3·55	11·00	8·10	5·50
1·00	·40	4·00	2·40	2·85	4·40	3·20	2·55
2·04	3·80	9·40	4·10	5·40	10·40	5·20	5·10
·48	3·20	6·40	1·30	·70	5·60	3·30	2·00
2·55	6·20	10·50	4·30	4·90	14·70	8·00	5·60
3·30	2·10	6·40	3·20	2·80	3·60	2·90	3·20
4·83	2·90	8·30	3·70	2·75	1·60	4·70	3·25
27·36	40·40	73·50	34·10	37·30	83·50	59·80	45·10

Division XVI.—East Midland Counties (*continued*).

Perth (*continued*).					**Forfar.**		
rly Bank, Perth.	**Scone Palace.**	**Tyndrum Mines.**	**Stanley.**	**Belmont Meigle.**	**Dundee.**	**Barry.**	**Craigton.**
ft. 3 in. 66 ft.	2 ft. 6 in. 80 ft. ?	0 ft. 3 in. 792 ft.	1 ft. 0 in. 200 ft.	0 ft. 6 in. 300 ft.	0 ft. 0 in. 60 ft.	0 ft. 3 in. 35 ft.	0 ft. 0 in. 440 ft.
in.	in.	in.	in.	in.	in.	in.	in.
3·55	2·90	8·20	2·30	2·90	3·75	3·03	3·50
2·17	1·00	7·90	2·20	·90	1·28	·94	1·73
2·74	2·88	8·30	2·50	2·10	1·93	2·23	2·55
·56	·22	1·20	·38	·30	·33	·41	·80
1·52	·98	4·90	1·35	1·70	1·10	·13	1·05
7·11	5·50	6·40	6·37	5·40	5·65	4·38	5·30
3·59	2·67	2·70	3·13	3·10	3·10	2·62	3·80
3·45	1·32	6·60	2·50	3·10	3·00	2·65	3·00
1·16	·80	4·70	·66	1·80	·85	1·50	1·00
3·14	2·00	15·80	1·50	1·50	2·00	2·43	2·67
4·25	3·23	3·50	3·40	4·90	5·20	4·68	6·37
4·64	5·25	2·50	4·82	4·80	6·52	3·85	5·80
37·88	28·75	72·70	31·11	32·50	34·71	28·85	37·57

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SCOTLAND.

Division XVI.—East Midland Counties (*continued*).						Div. XVII N.-E. Cos.
Forfar (*continued*).						Kincardin
1860.	Kettins.	Hillhead.	Seichen.	Arbroath.	Museum, Montrose.	The Burn, Brechin.
Height of Rain-gauge above Ground..	1 ft. 0 in.	0 ft. 0 in.	0 ft. 0 in.	2 ft. 0 in.	0 ft. 3 in.	0 ft. 6 in.
Sea-level.	218 ft.	500 ft.	550 ft.	65 ft.	8 ft.	210 ft.
	in.	in.	in.	in.	in.	in.
January	3·41	3·48	3·51	3·41	2·33	3·60
February	1·54	1·76	1·77	1·05	·82	2·70
March	2·31	2·50	2·65	1·96	1·62	2·70
April	·45	·84	·93	·78	·60	1·20
May	1·21	1·17	1·61	1·18	1·10	2·30
June	6·77	5·68	6·00	4·75	3·30	6·10
July	3·12	3·00	3·00	1·87	1·30	3·10
August	3·48	3·07	3·15	2·96	4·82	4·10
September	·75	·95	·91	1·04	·75	·50
October	2·16	2·85	2·80	2·51	1·70	2·80
November	5·12	6·45	6·70	4·33	3·75	5·80
December	6·07	5·68	5·77	4·64	4·23	6·60?
Totals	36·39	37·43	38·80	30·48	26·32	41·50?

Division XVIII.—North-Western Counties.						
Ross.			Inverness.			
1860.	Stornoway, Isle of Lewes.	Bernera, Isle of Lewes.	Beaufort Castle.	Culloden House.	Portree, Isle of Skye.	Raasay House.
Height of Rain-gauge above Ground..	0 ft. 3 in.	0 ft. 6 in.	4 ft. 6 in.	3 ft. 0 in.	0 ft. 1 in.	4 ft. 0 in.
Sea-level.	70 ft.	15 ft.	40 ft.	104 ft.	60 ft.	80 ft.
	in.	in.	in.	in.	in.	in.
January	2·79	1·90	2·03	1·30	9·05	3·90
February	2·15	1·80	2·25	1·22	11·05	4·40
March	5·80	4·00	4·64	3·14	11·75	6·90
April	2·60	·68	1·24	1·50	5·20	2·40
May	4·10	·70	·92	1·00	5·56	4·15
June	2·44	1·88	3·19	2·18	3·96	3·25
July	1·46	3·90	1·85	1·81	2·77	2·65
August	5·03	3·28	3·08	2·93	4·15	4·40
September	3·98	4·80	1·20	1·23	8·20	6·50
October	8·44	3·40	4·67	2·46	17·86	13·70
November	2·30	3·90	1·41	1·53	2·86	2·40
December	1·71	2·13	·96	1·21	5·58	2·95
Totals	42·80	32·37	27·44	21·51	87·99	57·60

SCOTLAND.

Division XVII.—North-Eastern Counties (*continued*).							
Kincardine (*continued*).				Aberdeen.			Elgin.
alnakettle, ettercairn.	Bogmuir, Fettercairn.	Strachan, Banchory.	Banchory, Aberdeen.	Braemar.	Aberdeen.	Castle Newe.	Elgin.
ft. 3 in. 450 ft.	0 ft. 3 in. 200 ft.	1 ft. 6 in. 200 ft.	0 ft. 4 in. 95 ft.	4 ft. 0 in. 1110 ft.	0 ft. 4 in. 100 ft.	1 ft. 0 in. 915 ft.	0 ft. 0 in. 125 ft.
in.	in.	in.	in.	in.	in.	in.	in.
4·12	3·40	3·50	4·20	2·78	4·75	2·67	1·67
2·44	2·80	2·20	2·50	2·40	2·10	3·92	1·35
2·95	2·60	2·88	2·30	3·04	2·45	2·57	2·65
1·65	1·10	1·56	1·50	1·22	1·30	2·01	1·38
1·35	1·00	1·57	1·10	1·85	1·30	2·43	1·57
6·38	5·30	4·34	3·40	5·70	3·60	5·69	2·36
2·75	3·00	2·66	·70	1·67	1·25	3·06	2·66
4·83	3·80	5·03	2·90	4·94	3·40	4·74	3·22
·73	·40	·96	1·00	1·09	1·55	1·06	2·24
3·20	2·30	1·85	2·60	2·80	2·50	2·53	2·67
6·35	5·20	5·76	5·50	1·18	4·90	3·42	1·81
6·06	6·50	5·85	6·20	4·69	5·60	6·39	2·13
42·81	37·40	38·16	33·90	33·36	34·70	40·49	25·71

.XVIII. (*cont.*).	Division XIX.—Northern Counties.						Div. XX. IRELAND
NVERNESS ontinued).	Sutherland.			Orkney.		Shetland.	Cork.
ch Maddy.	Dunrobin Castle.	Scourie.	Tongue House.	Balfour Castle, Kirkwall.	Sandwick.	Bressay.	Royal Institution, Cork.
3 ft. 0 in. 20 ft. ?	0 ft. 4 in. 6 ft.	0 ft. 2 in. 20 ft.	0 ft. 2 in. 30 ft. ?	0 ft. 6 in. 50 ft.	2 ft. 0 in. 78 ft.	0 ft. 9 in. 20 ft.	50 ft. 0 in. 80 ft.
in.	in.	in.	in.	in.	in.	in.	in.
4·10	1·90	2·50	2·60	2·20	3·00	4·70	5·39
2·85	2·70	3·80	2·50	1·30	1·81	2·30	1·36
6·00	3·00	5·10	3·80	2·60	3·40	4·70	2·54
1·50	1·30	1·80	1·00	2·40	1·23	1·15	1·05
3·40	1·90	2·70	3·40	1·90	2·28	2·55	3·32
1·00	3·50	2·80	2·80	1·40	1·69	1·50	4·45
3·20	1·90	2·10	1·40	·18	1·00	·90	1·06
4·05	3·80	3·20	5·30	4·00	4·88	3·50	2·87
4·60	1·30	4·10	4·30	1·90	4·65	3·70	1·66
8·70	4·00	6·90	6·70	4·90	5·49	5·60	1·29
1·90	2·30	1·40	2·50	3·00	3·51	3·40	2·83
1·35	1·80	1·90	5·80	2·40	5·02	2·80	4·09
42·65	29·40	38·30	42·10	28·18	37·96	36·80	31·91

IRELAND.

Division XX. (*continued*).

		Waterford.			Clare.	Queen's County.	Wicklow.
1860.		Waterford.	Portlaw.	Rath-cullihecn.	Killaloe.	Portarlington.	Fassaroe, Bray.
Height of Rain-gauge above	Ground..	4 ft. 0 in.	20 ft. 0 in.	1 ft. 6 in.	5 ft. 0 in.	9 ft. 0 in.	3 ft. 0 in.?
	Sea-level.	60 ft.	50 ft. ?	135 ft.	128 ft.	245 ft.	250 ft.?
		in.	in.	in.	in.	in.	in.
January		6·05	7·50	5·22	7·07	4·37	10·79
February		1·34	1·92	1·33	3·01	1·30	1·65
March		1·31	2·84	1·97	4·85	2·76	2·95
April		2·19	1·44	1·45	2·12	2·38	1·49
May		3·35	3·92	2·38	4·52	3·09	2·74
June		6·54	5·68	5·72	5·84	4·73	9·73
July		2·44	1·97	2·02	2·24	2·78	2·71
August		5·39	7·12	5·85	7·38	5·30	6·46
September		2·29	2·09	2·62	2·62	1·40	2·27
October		2·77	2·99	2·78	4·58	2·24	5·58
November		3·54	5·40	3·28	2·64	2·52	4·01
December		3·65	3·84	2·94	1·89	1·97	7·14
Totals		40·86	46·71	37·56	48·76	34·84	57·52

ENGLAND AND WALES, 1861.

Division I.—Middlesex.

		Middlesex.					
1861.		Chiswick.	Guildhall.	Guildhall.	Chiswell Street.	St. John's Wood.	Camden Town.
Height of Rain-gauge above	Ground..	....	5 ft. 0 in.	77 ft. 0 in.	50 ft. 0 in.	0 ft. 0 in.	0 ft. 4 in.
	Sea-level.	....	51 ft.	123 ft.	....	161 ft.	100 ft.
		in.	in.	in.	in.	in.	in.
January		·82	·45	·40	1·41	·55	·43
February		1·41	1·58	1·53	1·58	1·80	1·93
March		1·89	2·07	1·94	2·17	2·22	2·42
April		1·44	1·30	1·21	1·30	1·26	1·31
May		1·31	1·26	1·13	1·30	1·36	1·40
June		2·35	2·49	2·32	3·04	1·63	2·13
July		1·90	2·47	2·20	2·71	2·57	2·42
August		·50	·69	·60	·72	·89	·94
September		1·78	1·63	1·44	1·57	2·06	2·15
October		1·04	·86	·68	·92	·97	1·05
November		4·10	4·70	4·09	4·84	4·55	4·65
December		·94	1·37	1·24	1·29	1·57	1·51
Totals		19·48	20·87	18·78	22·85	21·43	22·34

IRELAND.

Division XX. (*continued*).

GALWAY.	DUBLIN.			MAYO.	SLIGO.	BELFAST.	
Galway.	Black Rock, Dublin.	Glasnevin.	Monkstown.	Cong, Lough Corrib.	Observatory, Markree.	Queen's College, Belfast.	Linen Hall, Belfast.
0 ft. 0 in. 40 ft.	28 ft. 0 in. 96 ft.	6 ft. 0 in. 65 ft.	0 ft. 6 in. 90 ft.	20 ft. 0 in. 60 ft. ?	16 ft. 3 in. 145 ft.	9 ft. 0 in. 58 ft.	4 ft. 0 in. 12 ft.
in.	in.	in.	in.	in.	in.	in.	in.
6·85	3·05	3·54	4·63	7·92	5·01	6·46	5·47
3·98	·29	·69	·50	3·66	2·83	2·52	2·48
1·17	1·64	1·95	1·94	3·99	4·13	3·14	3·70
3·10	1·52	2·23	2·08	1·76	1·94	2·07	2·21
3·68	1·90	3·67	2·15	4·55	5·20	2·66	3·69
3·45	4·29	3·38	5·18	5·31	6·20	5·79	6·07
2·05	1·70	2·67	2·04	1·67	2·48	2·31	2·64
5·00	4·53	4·18	5·10	4·40	6·87	4·61	4·78
1·72	1·68	1·99	1·99	1·92	1·38	1·21	1·29
3·84	1·80	1·87	2·04	4·17	3·76	2·78	2·57
2·04	1·88	2·31	2·28	1·51	2·37	1·71	1·57
2·48	2·42	2·60	3·33	2·58	1·57	2·97	3·37
39·36	26·70	31·08	33·26	43·44	43·74	38·23	39·84

ENGLAND AND WALES, 1861.

Division I.—MIDDLESEX (*continued*).						Division II. S.-EAST. COUNTIES.	
MIDDLESEX (*continued*).						SURREY.	
Hackney.	Finchley Road.	Finchley Road.	Tottenham.	Vicarage, Tottenham.	Vicarage, Enfield.	Ham, Red Hill.	Kitlands, Dorking.
0 ft. 6 in. 40 ft.	0 ft. 4 in. 270 ft.	36 ft. 4 in. 306 ft.	0 ft. 3 in. 60 ft.	0 ft. 0 in. ………	30 ft. 0 in. 140 ft.	0 ft. 4 in. ………	4 ft. 8 in. 580 ft.
in.	in.	in.	in.	in.	in.	in.	in.
·44	·45	·28	·48	} 4·96 {	·64	·62	·95
1·86	1·87	1·17	1·77		1·84	2·80	2·05
2·30	2·33	1·48	2·14		2·26	2·41	3·20
·72	1·26	·98	·84	·69	·93	·91	·97
1·70	1·24	·83	1·25	1·18	1·07	·32	1·62
1·78	1·82	1·26	1·75	1·83	1·14	2·93	3·53
2·42	2·72	2·02	2·48	2·23	3·07	3·11	4·84
·58	1·02	·44	·76	·74	1·11	·66	·99
1·66	1·77	1·29	1·90	1·86	1·54	2·41	2·94
·84	1·04	·74	1·00	·86	1·59	1·62	1·59
5·30	3·46	2·35	4·44	5·23	3·58	5·27	6·09
1·42	1·65	1·12	1·37	1·83	1·25	1·09	1·74
21·02	20·63	13·96	20·18	21·41	20·02	24·15	30·51

ENGLAND AND WALES.

Division II.—South-Eastern Counties (*continued*).

Surrey (*continued*).

1861.	Deepdene, Dorking.	Denbies, Dorking.	Brockham, Betchworth.	The Holmes, Betchworth.	Cobham.	Weybridge Heath.
Height of Rain-gauge above Ground.. Sea-level.	2 ft. 0 in.	25 ft. 0 in. 600 ft.	0 ft. 6 in. 300 ft.	0 ft. 6 in. 300 ft.	0 ft. 6 in. 110 ft.	0 ft. 6 in. 120 ft.
	in.	in.	in.	in.	in.	in.
January	·83	·08	·42	1·47	·31	·45
February	2·92	·62	2·40	2·37	2·03	1·98
March	3·43	3·24	2·63	2·60	2·04	2·25
April	·87	2·17	·83	·87	·82	·80
May	1·30	·42	1·31	1·36	1·14	1·38
June	2·68	3·60	2·38	2·22	3·89	2·41
July	3·35	2·10	3·64	3·42	1·92	2·65
August	1·05	1·00	·51	·54	·53	·50
September	2·77	2·19	2·63	2·75	1·54	1·65
October	1·38	2·14	1·33	1·63	·89	·85
November	5·45	5·33	4·92	5·24	4·47	4·73
December	1·35	2·33	1·78	1·50	1·19	1·40
Totals	27·38	25·22	24·78	25·97	20·77	21·05

Division II.—South-Eastern Counties (*continued*).

	Kent (*continued*).				**Sussex.**	
1861.	Welling, Bexley Heath.	Greenwich Observatory.	Greenwich Observatory.	Greenwich Observatory.	Aldwick, near Bognor.	Worthi
Height of Rain-gauge above Ground.. Sea-level.	6 ft. 0 in. 150 ft.	0 ft. 5 in. 155 ft.	22 ft. 4 in. 177 ft.	50 ft. 8 in. 205 ft.	0 ft. 6 in. 20 ft.	0 ft. 0 in. 10 ft.
	in.	in.	in.	in.	in.	in.
January	·47	·60	·30	·20	·10	·62
February	1·91	1·80	1·40	1·00	1·17	2·01
March	2·14	2·20	1·60	1·10	1·71	2·42
April	·83	·80	·80	·80	·58	·49
May	2·00	1·60	1·50	1·20	1·61	1·60
June	1·90	1·80	1·70	1·30	2·04	1·97
July	2·24	2·10	1·90	1·70	2·82	3·23
August	·77	·60	·40	·30	·48	1·04
September	1·25	1·50	1·10	·90	2·77	3·98
October	·80	·90	·70	·60	1·29	1·85
November	4·75	5·20	3·80	2·90	5·23	7·63
December	1·10	1·30	·90	·90	1·40	2·24
Totals	20·16	20·40	16·10	12·90	21·20	29·08

ENGLAND AND WALES.

Division II.—SOUTH-EASTERN COUNTIES (*continued*).

SURREY (*continued*).			KENT.				
Kew Observatory.	Wandsworth.	Battersea.	Dover.	Hunton Court, Staplehurst.	Linton Park.	Tunbridge.	Maidstone.
0 ft. 0 in. 18 ft.	5 ft. 0 in. 58 ft.	0 ft. 0 in. 13 ft.	0 ft. 8 in. 30 ft. ?	0 ft. 8 in.	0 ft. 6 in. 200 ft.	0 ft. 0 in. 125 ft.	4 ft. 0 in. 60 ft.
in.	in.	in.	in.	in.	in.	in.	in.
·46	....	1·12	1·85	·22	·38	·40	·48
1·51	....	1·69	1·44	1·73	1·82	1·75	1·87
2·30	2·75	2·28	1·91	2·35	2·46	2·19	2·91
1·08	1·14	1·24	·89	·83	·97	·62	1·00
1·06	1·94	1·21	1·60	1·13	1·19	1·56	1·10
2·29	2·53	2·63	3·49	2·17	2·14	2·08	1·70
2·10	2·09	2·27	1·88	1·65	3·25	2·80	2·92
·59	·66	·06	2·29	·90	·93	1·00	1·15
1·83	·79	2·60	4·16	2·14	2·16	2·08	1·97
·75	·93	1·13	1·51	·91	·89	1·09	·75
3·96	4·99	4·38	5·99	6·07	6·10	5·87	6·31
·93	1·23	1·35	1·40	1·59	1·72	1·67	1·75
18·86	....	21·96	28·41	21·69	24·01	23·11	23·91

Division II.—SOUTH-EASTERN COUNTIES (*continued*).

SUSSEX (*continued*).							
Thorney Island, near Emsworth.	Chichester Museum.	Shopwyke, Chichester.	Bleak House, Hastings.	High Wickham, Hastings.	St. Leonards.	Fairlight.	Funtington, Chichester.
0 ft. 6 in. 10 ft.	0 ft. 6 in. 20 ft. ?	1 ft. 3 in. 72 ft. ?	4 ft. 0 in. 80 ft.	0 ft. 0 in. 212 ft.	0 ft. 0 in. 10 ft.	0 ft. 9 in. 498 ft.	1 ft. 0 in. 10 ft.
in.	in.	in.	in.	in.	in.	in.	in.
·52	·45	·53	·61	·43	·42	·44	2·47
1·98	2·01	1·75	·88	·97	·91	·93	
2·56	2·29	2·29	2·34	2·23	2·52	2·42	2·01
·52	·60	·51	·25	1·23	·78	·81	1·26
1·65	1·60	1·25	1·36	1·19	1·61	1·93	1·42
2·36	1·96	1·49	4·62	4·23	6·12	4·85	1·58
3·44	3·91	3·98	....	2·14	2·10	2·66	4·06
·72	·47	·66	....	·91	1·18	1·25	·34
3·06	3·31	3·27	....	3·26	4·06	3·74	2·00
1·50	2·52	2·03	2·35	1·28	1·34	1·62	6·10
4·36	4·49	4·43	....	5·45	6·63	7·01	
1·45	1·54	1·59	....	1·54	1·62	1·49	1·04
24·12	25·15	23·78	....	24·86	29·29	29·15	22·28

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ENGLAND AND WALES.

Division II.—South-Eastern Counties (*continued*).

Sussex (*continued*).

1861.		Slindon.	Dale Park, Arundel.	Westdean, Chichester.	Chilgrove, Chichester.	Hurstpier-point.	Uckfield
Height of Rain-gauge above	Ground..	1 ft. 0 in.	4 ft. 0 in.	0 ft. 6 in.	0 ft. 6 in.	0 ft. 0 in.	6 ft. 0 in.
	Sea-level.	190 ft.	316 ft.	250 ft.	284 ft. ?	120 ft.	200 ft.
		in.	in.	in.	in.	in.	in.
January		·59	·31	·75	·78	·34	·23
February		2·18	·29	2·56	2·08	1·25	1·78
March		2·86	2·86	3·25	2·96	2·15	2·51
April		·85	·94	·79	·76	·35	·69
May		1·37	1·82	1·79	1·55	1·24	1·56
June		2·30	2·89	2·45	2·34	7·57	2·88
July		3·75	3·62	4·45	4·81		2·85
August		·79	1·27	1·18	·73	·84	1·16
September		4·03	2·20	3·94	3·94	3·65	3·70
October		2·30	2·02	2·45	1·81	1·51	1·85
November		5·30	3·96	5·12	4·99	7·09	7·50
December		1·86	1·93	2·06	1·92	1·75	1·64
Totals		28·18	24·11	30·79	28·67	27·74	28·35

Division II.—South-Eastern Counties (*continued*).

Hampshire (*continued*).

1861.		Fareham.	Ordnance S. Office, Southampton.	Ordnance S. Office, Southampton.	Gas Works, Southampton.	Petersfield.	Peters
Height of Rain-gauge above	Ground..	1 ft. 0 in.	18 ft. 6 in.	0 ft. 0 in.	10 ft. 0 in.	....	0 ft. 0 in.
	Sea-level.	8 ft.	94 ft.	75 ft.	20 ft.	....	200 ft.
		in.	in.	in.	in.	in.	in.
January		·80	·76	·81	0·00	·77	·96
February		5·38	2·11	2·37	1·52	3·29	2·90
March		2·15	2·46	3·00	1·83	4·51	4·18
April		·47	·40	·41	·27	·40	·61
May		1·39	1·60	1·63	1·39	1·77	1·64
June		3·54	3·68	3·97	3·29	2·85	2·80
July		3·82	3·45	4·07	3·19	5·17	5·31
August		·55	·79	·87	·60	1·33	1·09
September		3·24	2·62	3·07	2·90	4·50	4·28
October		1·53	·82	1·09	·73	1·88	1·64
November		4·91	4·58	6·47	4·61	7·42	6·88
December		1·38	1·46	2·09	1·16	·53	1·43
Totals		29·16	24·73	29·85	21·49	34·42	33·71

ENGLAND AND WALES.

Division II.—South-Eastern Counties (*continued*).

Sussex (*continued*).					Hampshire.		
sted Park.	Rectory, Maresfield.	Forest Lodge, Maresfield.	Fair Oak, Rogate.	Crawley.	Ventnor.	Osborne.	Fareham.
....	1 ft. 0 in. 250 ft.	1 ft. 0 in. 300 ft.	0 ft. 6 in.	5 ft. 0 in. 300 ft.	3 ft. 0 in. 150 ft.	0 ft. 10 in. 172 ft.	0 ft. 0 in. 26 ft.
in.	in.	in.	in.	in.	in.	in.	in.
·61	·47	·61	2·16	·88	·38	·59	1·90
1·82	2·01	1·77		2·70	2·01	2·10	2·00
3·09	2·60	2·39	5·23	2·92	2·51	2·40	2·90
·70	·61	·49		·83	·45	·45	·30
1·76	1·87	1·27	2·13	2·33	2·05	1·56	1·80
2·65	2·55	2·16	1·17	3·49	2·90	2·54	4·10
3·63	3·09	3·03	4·54	5·01	2·71	3·10	3·70
1·06	1·05	·94	6·63	·86	·66	·66	1·40
4·76	4·38	4·26		4·19	3·27	3·65	3·60
2·28	1·96	1·79		1·97	1·89	1·70	1·40
8·40	7·76	6·72	2·59	6·48	7·10	5·74	5·70
1·81	1·90	2·13	4·12	2·59	1·36	1·40	1·80
32·57	30·25	27·56	28·57	34·25	27·29	25·89	30·60

Division II.—South-Eastern Counties (*continued*).

Hampshire (*continued*).					Berkshire.		
New resford.	Itchen Abbas.	Selborne.	Abbott's Ann, Andover.	Aldershott.	Royal Military College, Sandhurst.	Moulsford, Wallingford.	Long Wittenham, Abingdon.
....	3 ft. 0 in.	4 ft. 0 in. 400 ft. ?	1 ft. 4 in. 177 ft.	3 ft. 0 in. 325 ft.	5 ft. 0 in. 246 ft.	7 ft. 0 in. 200 ft.	1 ft. 0 in. 170 ft.
in.	in.	in.	in.	in.	in.	in.	in.
·35	1·11	1·22	·62	·56	·57	·69	·87
2·23	2·12	1·94	1·91	2·49	......	1·73	1·76
3·20	3·24	3·60	2·78	2·36	1·89	2·06	1·97
·48	·36	1·65	·28	·55	·68	·81	1·04
1·38	1·82	2·64	2·57	1·53	1·69	1·07	1·12
2·28	1·78	3·15	2·05	1·62	2·06	2·47	2·76
4·07	3·72	3·21	3·11	3·22	2·96	3·53	4·52
1·02	·95	2·35	·47	·75	·45	·78	·99
2·52	2·90	1·57	2·35	2·68	2·15	1·73	1·55
1·94	1·37	1·82	·96	1·00	1·18	1·14	1·20
5·41	3·75	5·16	3·82	4·61	3·60	3·05	3·20
2·13	1·95	2·09	1·58	1·17	1·20	1·70	1·69
27·01	25·07	30·40	22·50	22·54	......	20·76	22·67

ENGLAND AND WALES.

Division III.—South Midland Counties.

	Hertfordshire.					
1861.	Watford.	Field's Weir, Hoddesdon.	Gorhambury, St. Alban's.	Hemelhempstead.	Berkhampstead.	Royst
Height of Rain-gauge above Ground..	5 ft. 6 in.	2 ft. 0 in.	2 ft. 9 in.	3 ft. 0 in.	1 ft. 6 in.	0 ft. 7 in.
Height of Rain-gauge above Sea-level.	250 ft.	82 ft.	………	250 ft.	370 ft.	267 ft.
	in.	in.	in.	in.	in.	in.
January	·38	·85	·46	·50	·84	1·30
February	1·89	2·35	2·32	2·00	2·53	2·06
March	2·20	3·10	2·38	2·31	2·64	1·91
April	·65	1·28	·98	·80	·90	·83
May	·76	1·40	1·05	·91	·88	·97
June	2·73	1·95	2·75	2·45	2·07	1·90
July	3·37	2·00	3·16	3·92	4·13	3·29
August	·60	·55	·90	·55	1·02	·66
September	2·04	1·80	1·86	1·75	2·28	1·03
October	·75	·90	1·25	1·25	1·14	1·08
November	3·34	4·60	3·77	3·36	3·94	3·42
December	1·48	1·20	1·25	1·40	1·73	1·36
Totals	20·19	21·98	22·13	21·20	24·10	19·81

Division III.—South Midland Counties (*continued*).

	Northamptonshire.				Bedfordshire.	
1861.	Althorp House.	Wellingborough.	Oundle.	Marholm, Peterborough.	Aspley.	Cardi
Height of Rain-gauge above Ground..	3 ft. 10 in.	0 ft. 2 in.	20 ft. 0 in.	0 ft. 6 in.	0 ft. 6 in.	………
Height of Rain-gauge above Sea-level.	………	………	124 ft.	………	460 ft.	………
	in.	in.	in.	in.	in.	in.
January	·68	1·36	1·10	1·78	·93	·95
February	4·18	2·52	2·03	1·32	2·16	1·99
March	2·03	2·06	1·48	4·45	2·31	1·76
April	·56	1·58	·97	·74	1·32	·87
May	1·17	1·27	1·07	·91	1·36	1·12
June	2·15	2·83	1·64	1·88	3·05	2·14
July	3·60	4·13	5·63	8·47	4·52	3·95
August	·18	·73	·57	1·29	·44	·35
September	1·20	1·60	1·21	·73	1·53	1·03
October	1·22	1·33	·93	·76	1·07	·84
November	2·62	3·01	2·64	2·17	2·99	2·65
December	1·17	1·33	1·18	·72	1·61	1·38
Totals	20·76	23·75	20·45	25·26	23·29	19·03

ENGLAND AND WALES.

Division III.—South Midland Counties (*continued*).							
Buckinghamshire.		Oxfordshire.					
Hartwell House, Aylesbury.	Hartwell Rectory, Aylesbury.	Rose Hill, Oxford.	Observatory, Oxford.	Observatory, Oxford.	Banbury.	Banbury.	Banbury.
1 ft. 0 in. 250 ft.	4 ft. 0 in. 290 ft.	7 ft. 9 in. 270 ft.	0 ft. 0 in. 208 ft.	22 ft. 0 in. 230 ft.	7 ft. 4 in. 350 ft.	4 ft. 9 in. 340 ft.	....
in.	in.	in.	in.	in.	in.	in.	in.
·46	·20	·64	·66	·60	·53	·50	·54
1·64	1·50	1·19	1·90	1·72	2·68	2·71	2·75
2·22	1·70	1·53	1·68	1·34	2·27	2·34	1·94
·74	·86	·98	·69	·60	1·21	1·30	1·37
·73	·64	1·23	1·36	·90	1·62	1·62	1·40
2·02	1·71	2·65	3·12	2·95	2·15	2·03	2·00
3·74	3·31	6·64	5·15	4·62	3·36	3·26	3·25
·78	·46	1·04	·60	·54	·43	·37	·57
1·80	1·51	2·53	1·94	1·79	2·51	2·43	2·48
1·16	1·03	1·97	1·58	1·52	1·32	1·28	·99
2·60	2·67	4·23	3·07	2·25	2·73	2·74	2·83
1·54	1·52	2·17	1·65	1·46	1·53	1·51	1·22
19·43	17·11	26·80	23·40	20·29	22·34	22·09	21·34

Div. III.—S. Midland Counties (*cont.*).				Division IV.—Eastern Counties.			
Bedfordshire.	Cambridgeshire.			Essex.			
Bedford.	Observatory, Wisbech.	North Brink, Wisbech.	Mid-Level Sluice, Wisbech.	Leyton.	Epping.	Witham.	Ashdon.
3 ft. 6 in. 104 ft.	0 ft. 6 in. 8 ft.	0 ft. 8 in. 11 ft.	....	0 ft. 4 in. 93 ft.	6 ft. 0 in. 360 ft.	1 ft. 6 in. 20 ft.	1 ft. 0 in. 300 ft.
in.	in.	in.	in.	in.	in.	in.	in.
·98	·91	·86	·59	·69	1·03	1·26	1·72
1·80	1·55	1·77	1·68	1·76	1·50	·61	2·32
1·93	1·63	1·55	1·44	2·10	2·04	2·48	1·81
·91	·95	·99	·60	·88	1·35	·52	·45
1·06	1·25	1·34	1·31	1·14	1·55	·90	1·29
1·96	3·22	3·18	2·31	1·94	2·20	2·22	1·79
3·34	3·62	3·80	4·67	2·57	1·85	3·62	2·40
·28	·55	·69	·50	·97	·75	·63	·53
1·17	1·65	1·73	1·37	1·95	1·65	1·27	1·23
·86	·71	·78	·80	·99	1·10	·48	·98
2·84	3·65	3·85	3·33	4·09	4·35	4·01	3·06
1·30	1·57	1·65	1·38	1·33	1·05	·83	·96
18·43	21·26	22·19	19·98	20·41	20·42	18·83	18·54

ENGLAND AND WALES.

Division IV.—Eastern Counties (*continued*).						
	Essex (*continued*).			**Suffolk.**		
1861.	Frating, Colchester.	Dunmow.	Bocking, Braintree.	Grundisburgh.	Bury St. Edmunds.	Westley, Bury.
Height of Rain-gauge above Ground ..	....	....	3 ft. 0 in.	4 ft. 1 in.	2 ft. 0 in.	1 ft. 6 in.
Height of Rain-gauge above Sea-level.	....	100 ft. ?	200 ft. ?	....	....	....
	in.	in.	in.	in.	in.	in.
January	·27	·60	1·36	1·10	1·31	1·03
February	1·52	2·08	2·55	1·74	2·69	2·36
March	1·80	1·81	2·55	1·33	1·95	2·04
April	·66	·92	·77	·40	·82	·74
May	·95	1·08	·85	1·26	1·14	1·10
June	1·73	1·87	2·08	1·11	2·12	1·57
July	3·14	2·10	2·34	2·02	2·20	2·13
August		·38	·65	·94	·61	·49
September	1·44	1·45	1·77	1·53	1·27	·92
October	·58	·46	·66	·55	·80	·53
November	3·47	3·20	3·33	4·08	3·37	3·64
December	1·03	1·22	·90	1·40	1·22	1·17
Totals	16·59	17·17	19·81	17·46	19·50	17·71

Division IV.—Eastern Counties (*continued*).				Division V. South-Western Counties.		
	Norfolk (*continued*).			**Wiltshire.**		
1861.	Burnham.	Holkham.	Holkham.	Alderbury, Salisbury.	Baverstock.	Marlborou
Height of Rain-gauge above Ground ..	4 ft. 6 in.	0 ft. 0 in.	4 ft. 0 in.	0 ft. 6 in.	3 ft. 0 in.	4 ft. 0 in.
Height of Rain-gauge above Sea-level.	102 ft.	39 ft.	43 ft.	....	....	....
	in.	in.	in.	in.	in.	in.
January	·99	1·00	·37	·50	·50	·90
February	2·39	2·35	2·33	2·44	2·55	2·60
March	2·73	2·25	2·11	2·96	2·85	3·41
April	1·35	1·65	1·65	·35	·25	·31
May	1·97	1·70	1·69	1·73	1·65	1·63
June	1·54	1·30	1·28	2·26	2·50	3·58
July	2·78	1·90	1·84	3·95	4·05	4·38
August	·60	·55	·64	·45	·60	·84
September	2·24	1·90	1·88	3·27	3·15	3·21
October	·54	·43	·51	1·12	1·40	1·78
November	6·14	5·50	5·19	4·19	5·00	4·45
December	1·51	1·27	1·29	1·92	2·25	1·81
Totals	24·78	21·80	20·78	25·14	26·75	28·90

ENGLAND AND WALES.

Division IV.—Eastern Counties (*continued*).

Suffolk (*continued*).					Norfolk.		
Barton Hall, Bury.	Thwaite.	Thurston Lodge, Bury.	Nether Hall, Thurston.	Culford, Bury.	Diss.	Norwich.	Egmere.
1 ft. 0 in. ………	3 ft. 6 in. 150 ft.	2 ft. 0 in. ………	0 ft. 0 in. ………	1 ft. 3 in. ………	0 ft. 6 in. 115 ft.	0 ft. 0 in. 30 ft.	4 ft. 0 in. 150 ft.
in.	in.	in.	in.	in.	in.	in.	in.
2·27	1·14	1·02	1·00	·79	·60	1·28	1·00
2·33	2·79	2·05	2·82	2·51	2·40	2·75	2·69
1·60	2·36	1·51	1·87	1·77	1·70	2·60	2·21
·84	1·26	·68	·50	·77	·85	·90	1·86
·35	1·25	·75	·17	1·00	1·00	1·34	2·07
2·30	1·12	2·53	1·71	2·62	1·20	1·32	1·45
2·40	4·50	2·54	1·77	2·64	4·70	4·93	2·82
·62	·86	·70	2·13	·52	·80	·48	·66
·87	1·73	·97	1·30	1·16	1·28	2·31	2·99
1·88	·74	·90	1·00	1·03	·45	·49	·72
3·88	4·34	2·81	3·27	3·47	3·40	5·01	4·97
1·36	1·53	1·00	1·44	1·23	1·37	1·39	1·38
20·70	23·62	17·46	18·98	19·51	19·75	24·80	24·82

Division V.—South-Western Counties (*continued*).

Wiltshire (*continued*).	Dorset.						Devonshire.
Castle House, Calne.	Portland.	Encombe, Wareham.	Little Bridy.	Bridport.	Netherbury.	Forde Abbey.	Kingsbridge.
28 ft. 0 in. 348 ft.	2 ft. 0 in. 52 ft.	1 ft. 0 in. 150 ft.	0 ft. 4 in. 348 ft.	0 ft. 11 in. 95 ft. ?	0 ft. 0 in. 50 ft. ?	0 ft. 6 in. ………	0 ft. 6 in. 143 ft.
in.	in.	in.	in.	in.	in.	in.	in.
·72	·65	1·15	·83	·60	·89	1·03	1·90
1·91	2·72	2·84	4·81	3·92	5·15	4·72	2·20
2·31	2·77	4·11	4·46	3·44	3·97	3·84	3·94
·57	·25	·45	·48	·51	·55	·58	·94
1·12	·51	1·57	1·54	1·00	1·03	1·36	2·05
2·64	2·22	3·82	4·27	4·63	5·00	4·26	3·38
3·41	2·79	4·60	5·54	4·03	4·34	3·27	4·94
·78	·71	1·05	·93	·70	4·16	·76	1·46
2·46	2·23	2·46	3·51	2·73		2·39	3·13
1·58	1·18	2·45	2·20	1·70	2·29	3·01	2·63
3·33	4·68	6·49	5·54	4·58	6·12	5·57	5·61
1·43	1·36	1·50	3·12	1·83	2·54	2·12	2·12
22·26	22·07	32·49	37·23	29·67	36·04	32·91	34·30

ENGLAND AND WALES.

Division V.—South-Western Counties (*continued*).

Devonshire (*continued*).

1861.	Ham, Plymouth.	Saltram Gardens.	Ridgeway, Plympton, St. Mary.	Torrhill, Ivy Bridge.	Goodamoor, Plympton, St. Mary.	Torquay.
Height of Rain-gauge above Ground	3 ft. 0 in.	0 ft. 3 in.	0 ft. 6 in.	0 ft. 4 in.	0 ft. 2 in.	1 ft. 0 in.
Height of Rain-gauge above Sea-level	94 ft.	96 ft.	116 ft.	260 ft.	580 ft.	150 ft.
	in.	in.	in.	in.	in.	in.
January	2·31	2·75	2·53	2·74	2·76	·94
February	4·25	4·05	3·71	3·63	3·96	2·52
March	4·17	3·90	5·60	5·74	6·96	2·03
April	1·01	·80	·62	·53	·58	·19
May	1·03	1·01	·33	·68	·97	1·43
June	3·35	3·80	3·14	3·98	4·60	2·67
July	5·70	6·84	5·45	6·79	8·20	2·93
August	1·57	1·74	2·64	2·01	3·45	·47
September	2·91	3·81	4·51	3·83	5·92	1·95
October	2·99	2·34	3·29	2·44	3·81	1·20
November	6·42	7·50	7·55	6·76	8·21	4·14
December	3·52	3·15	3·61	3·12	4·24	2·27
Totals	39·23	41·69	42·98	42·25	53·66	22·74

Division V.—South-Western Counties (*continued*).

Devonshire (*continued*).

1861.	Albert Terrace, Exeter.	Albert Terrace, Exeter.	High Street, Exeter.	Institution, Exeter.	St. Thomas's, Exeter.	Clyst Hydon, Cullumpton.
Height of Rain-gauge above Ground	20 ft. 0 in.	0 ft. 0 in.	40 ft. 0 in.	13 ft. 7 in.	3 ft. 0 in.	0 ft. 6 in.
Height of Rain-gauge above Sea-level	160 ft.	140 ft.	170 ft.	155 ft.	50 ft.	200 ft.
	in.	in.	in.	in.	in.	in.
January	·83	1·12	·89	·58	·73	·43
February	2·82	3·40	3·17	3·12	2·25	2·58
March	2·68	3·43	3·08	3·60	3·57	3·90
April	·78	·87	·78	4·40	·20	·48
May	1·22	1·31	1·02	1·08	1·38	1·14
June	2·07	2·73	2·79	2·60	2·57	1·92
July	3·20	3·56	4·12	3·40	3·07	4·04
August	·82	1·02	1·05	·80	·83 ?	·82
September	1·75	2·00	2·04	1·80	2·27	2·08
October	1·72	1·94	1·97	2·10	2·59	1·63
November	3·88	4·23	4·00	3·90	5·27	4·07
December	2·07	2·41	3·01	2·42	3·60	2·12
Totals	23·84	28·02	27·92	25·80	28·33 ?	25·21

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ENGLAND AND WALES.

Division V.—South-Western Counties (*continued*).

Devonshire (*continued*).							
Highwick, Newton Bushel.	Teignmouth.	Westbrook, Teignmouth.	Institution, Tavistock.	Edgecumbe, Milton Abbot.	Dawlish.	Bovey Tracey.	St. Leonards, Exeter.
1 ft. 6 in. 300 ft.?	1 ft. 1 in. 60 ft.	0 ft. 3 in. 25 ft.	45 ft. 0 in. 298 ft.	0 ft. 8 in.	0 ft. 8 in. 62 ft.	0 ft. 6 in. 100 ft.	0 ft. 0 in. 160 ft.
in.	Observations rejected, position being unsuitable.	in.	in.	in.	in.	in.	in.
1·62		1·08	1·72	3·00	1·92	1·84	1·17
3·36		1·87	3·91	2·45	2·72	4·89	3·47
4·08		4·18	3·46	5·21	4·21	4·78	3·70
·23		·26	·66	·58	·56	·44	·63
1·60		1·76	·71	1·02	1·64	1·81	1·25
4·05		3·75	3·00	2·95	3·10	3·49	2·63
4·99		3·57	4·76	6·69	3·77	4·14	3·45
·78		·80	1·96	1·90	·26	·97	·95
2·55		2·17	2·87	3·77	1·56	3·28	1·92
2·62		2·18	2·40	2·48	2·25	2·10	1·99
5·66		6·49	5·28	5·20	5·80	5·56	4·11
2·91		2·25	3·72	4·24	2·18	3·43	2·69
34·45		30·36	34·45	39·49	29·97	36·73	27·96

Division V.—South-Western Counties (*continued*).

Devonshire (*continued*).					Cornwall.		
Broad-hembury, Honiton.	Tiverton.	Huntsham Court, Bampton	Castle Hill, South Molton.	Barnstaple.	Helston.	Penzance.	Tehidy Park, Redruth.
2 ft. 4 in. 600 ft.	0 ft. 2 in. 400 ft.?	1 ft. 1 in. 584 ft.	3 ft. 0 in. 160 ft.	0 ft. 6 in. 31 ft.	5 ft. 0 in. 110 ft.	3 ft. 0 in. 94 ft.	0 ft. 0 in. 100 ft.
in.	in.	in.	in.	in.	in.	in.	in.
·90	1·25	1·34	1·59	1·27	2·24	1·51	1·50
3·38	3·15	3·16	2·63	2·64	4·71	6·62	6·30
3·45	4·94	5·89	4·76	3·33	3·32	2·93	2·96
·58	·55	·65	·78	·66	1·65	1·39	1·15
1·06	·52	1·17	·83	1·40	1·60	1·29	2·00
2·66	4·06	3·98	3·95	2·54	1·74	2·17	2·85
3·90	4·57	6·55	5·63	5·80	5·02	6·81	4·73
1·17	1·77	2·22	3·45	2·76	1·49	2·02	1·75
2·65	2·92	4·17	5·04	4·00	3·06	3·51	3·77
2·24	1·62	2·20	3·04	2·94	2·63	1·92	3·40
4·53	5·37	5·84	7·19	7·60	7·39	7·23	6·45
2·00	2·83	2·79	2·30	2·21	2·77	3·58	3·70
28·52	33·55	39·96	41·19	37·15	37·62	40·98	40·56

ENGLAND AND WALES.

Division V.—South-Western Counties (*continued*).

Cornwall (*continued*).

1861.	Truro.	Bodmin.	Warleggan, Bodmin.	Pencarrow, Bodmin.	Treharrock House, Wadebridge.	St. Petroc Minor, Padstow.
Height of Rain-gauge above Ground..	40 ft. 0 in.	3 ft. 0 in	3 ft. 0 in.	4 ft. 0 in.	3 ft. 0 in.	0 ft. 2 in.
Height of Rain-gauge above Sea-level.	56 ft.	300 ft.	800 ft.	230 ft.	200 ft. ?	96 ft.
	in.	in.	in.	in.	in.	in.
January	1·12	2·29	2·65	2·29	1·87	1·39
February	5·84	4·87	4·78	4·65	3·92	4·93
March	2·74	3·45	4·58	4·05	3·37	3·79
April	·86	1·39	1·77	2·12	1·05	1·16
May	1·72	2·07	1·68	1·20	1·26	1·83
June	3·19	2·83	3·77	2·80	2·68	3·12
July	6·71	6·88	7·64	6·89	4·57	6·46
August	1·46	1·96	3·12	2·01	1·76	2·16
September	3·31	4·26	4·35	4·85	3·33	4·56
October	2·70	3·26	2·62	3·30	3·41	3·64
November	6·39	6·79	7·42	6·90	6·58	7·91
December	3·94	4·51	4·58	4·26	2·85	3·74
Totals	39·98	44·56	48·96	45·32	36·65	44·69

Div. V.—S.-W. Cos. (*cont.*).		Division VI.—West Midland Counties.				
Somerset (*continued*).		Gloucester.				
1861.	Bath.	Bristol Institution.	Clifton.	Clifton.	Cirencester.	The Sps. Gloucester.
Height of Rain-gauge above Ground..	50 ft. 0 in.	56 ft. 0 in.	0 ft. 6 in.	50 ft. 0 in.	1 ft. 0 in.	3 ft. 6 in.
Height of Rain-gauge above Sea-level.	150 ft.	98 ft.	192 ft.	242 ft.	446 ft.	50 ft.
	in.	in.	in.	in.	in.	in.
January	·89	1·14	1·03	·77	1·45	·87
February	3·57	2·59	2·75	2·30	2·95	1·97
March	2·86	3·05	2·94	2·36	2·90	1·90
April	·49	·25	·30	·22	·65	·54
May	1·41	1·09	1·39	1·06	1·15	1·20
June	5·14	3·44	3·34	2·93	2·65	2·38
July	3·92	4·03	4·53	4·22	3·94	4·14
August	1·18	2·28	2·57	2·32	·90	·70
September	4·86	3·65	3·86	3·55	3·16	1·95
October	2·23	1·99	2·28	2·06	1·74	1·46
November	5·66	4·74	4·86	4·30	4·10	2·60
December	1·81	1·34	1·46	1·30	1·80	1·59
Totals	34·02	29·59	31·31	27·39	27·39	21·30

ENGLAND AND WALES.

Division V.—South-Western Counties (*continued*).

Cornwall (*continued*).	Somerset.						
Rosecarrock, Port Isaac.	Taunton.	Long Sutton.	Street.	Street.	North Hill, Frome.	Mells, Frome.	Sidcot, Axbridge.
3 ft. 0 in. 180 ft.	1 ft. 3 in. 50 ft.?	0 ft. 0 in. 170 ft.?	1 ft. 6 in. 100 ft.	5 ft. 0 in. 100 ft.	0 ft. 3 in.	8 ft. 0 in. 300 ft.	4 ft. 7 in. 250 ft.
in.	in.	in.	in.	in.	in.	in.	in.
1·89	·95	·52	·52	·57	·70	·83	·88
3·38	2·46	3·01	2·74	2·39	3·10	3·62	2·93
3·30	2·53	2·87	2·92	2·76	3·00	4·52	2·68
·92	·36	·36	·34	·91	·65	·72	·49
1·10	1·31	1·34	1·27	1·17	1·65	1·35	1·53
2·97	3·60	3·69	2·79	2·77	2·88	2·99	4·09
5·47	4·35	3·14	3·95	3·58	3·32	3·81	4·29
2·07	·71	·52	1·25	1·09	·95	1·43	1·92
3·56	1·58	1·92	2·93	1·96	3·16	3·88	3·31
3·52	2·53	2·37	2·04	1·85	1·70	1·88	2·75
6·78	4·95	4·43	3·70	3·31	4·36	4·92	4·87
3·67	1·44	1·64	1·51	1·30	1·70	2·03	1·39
38·63	26·77	25·81	25·96	23·66	27·17	31·98	31·13

Division VI.—West Midland Counties (*continued*).

Gloucester (*continued*).		Shropshire.					
Asylum, Gloucester.	Twigworth, Gloucester.	Leysters, Leominster.	Cleobury Mortimer.	Knowbury, Ludlow.	Haughton Hall, Shifnall.	Shrewsbury.	Whittington, Oswestry.
1 ft. 0 in. 100 ft.	3 ft. 6 in.? 50 ft.?	0 ft. 6 in.	1 ft. 0 in. 700 ft.	0 ft. 6 in. 1000 ft.?	4 ft. 6 in. 450 ft.	4 ft. 4 in. 192 ft.	5 ft. 0 in. ....
in.	in.	in.	in.	in.	in.	in.	in.
1·11	·77	·37	·54	1·25	·74	·30	·54
2·03	2·23	3·08	2·63	2·55	1·73	2·00	3·04
2·06	1·75	2·73	3·20	2·69	3·19	2·90	3·30
·56	·62	·55	·87	·85	·83	·70	1·40
1·16	1·15	1·05	1·12	1·46	·75	·60	·86
2·38	1·89	3·16	2·94	3·51	4·28	2·80	2·18
4·15	3·80	5·45	5·83	5·68	4·97	2·70	4·51
·59	·43	1·12	1·09	1·31	1·10	·70	1·70
1·68	1·76	2·47	2·78	2·70	2·49	1·60	3·00
1·50	1·51	1·82	1·44	1·59	1·02	·80	2·01
2·88	2·64	2·76	2·26	2·48	1·69	1·00	2·98
1·73	1·61	1·97	1·58	1·85	1·01	·50	1·73
21·83	20·16	26·53	26·28	27·92	23·80	16·60	27·25

ENGLAND AND WALES.

Division VI.—West Midland Counties (*continued*).

	Shropshire (*continued*).		Worcester.		Warwick.	
1861.	Hengoed, Oswestry.	Leek.	Worcester.	Orleton, Tenbury.	Stoneleigh Abbey.	Rugby.
Height of Rain-gauge above Ground..	4 ft. 8 in.	25 ft. 0 in.	1 ft. 0 in.	0 ft. 9 in.	0 ft. 8 in.	2 ft. 4 in.
Height of Rain-gauge above Sea-level.	....	....	160 ft.	200 ft.	....	315 ft.
	in.	in.	in.	in.	in.	in.
January	·65	1·25	·58	1·03	·48	1·37
February	3·75	1·90	3·08	3·06	1·63	1·52
March	4·25	7·20	2·64	3·55	3·23	2·07
April	1·48	3·15	1·38	1·07	·80	·55
May	·75	1·60	1·13	1·32	1·06	1·03
June	2·61	3·00	2·13	3·02	3·01	1·88
July	4·47	4·05	4·67	6·69	4·30	4·62
August	1·95	2·10	·39	1·05	·63	·85
September	3·36	4·60	2·53	2·59	1·97	1·97
October	1·96	1·55	1·40	1·72	2·16	1·23
November	3·49	3·95	1·98	2·75	2·22	2·51
December	2·18	2·05	1·51	1·96	1·15	1·22
Totals	30·90	36·40	23·42	29·81	22·64	20·82

Division VII.—North Midland Counties (*continued*).

	Lincoln.					
1861.	Wytham-on-the-Hill.	Grantham.	Boston.	South Kyme, Sleaford.	Coleby, Lincoln.	Lincoln.
Height of Rain-gauge above Ground..	4 ft. 3 in.	0 ft. 0 in.	1 ft. 0 in.	0 ft. 0 in.	....	3 ft. 6 in.
Height of Rain-gauge above Sea-level.	....	179 ft.	....	9 ft.	....	26 ft.
	in.	in.	in.	in.	in.	in.
January	·20	·67	·93	1·09	·35	·30
February	1·70	1·79	2·12	1·70	1·53	1·45
March	2·10	1·83	1·65	1·50	1·37	1·02
April	·74	1·26	1·23	1·57	·78	1·19
May	1·20	1·23	1·55	1·62	·63	·80
June	2·83	2·29	2·49	3·55	3·49	3·20
July	3·70	4·35	3·74	4·33	4·02	2·96
August	·52	·48	·15	·39	·09	·35
September	1·70	1·40	1·38	1·08	1·17	1·13
October	·92	1·01	·90	·76	·66	·82
November	2·90	2·92	2·84	2·64	2·11	2·61
December	1·30	1·28	1·40	1·42	1·13	1·14
Totals	19·81	20·51	20·38	21·65	17·33	16·97

ENGLAND AND WALES.

Div. VI.—W. Midland Counties (*cont.*)		Division VII.—North Midland Counties.					
Warwick (*continued*).		Leicestershire.					Rutland.
Bloomsbury, Birmingham.	Camp Hill, Birmingham.	Wigston Grange.	Leicester.	Thornton Reservoir.	Rothley, Loughborough.	Belvoir Castle.	Empingham.
4 ft. 6 in. 340 ft.	9 ft. 0 in. 416 ft.	0 ft. 0 in.	1 ft. 3 in.	2 ft. 8 in.	0 ft. 4 in. 210 ft.	0 ft. 8 in. 237 ft.	4 ft. 0 in. ....
in.	in.	in.	in.	in.	in.	in.	in.
1·07	·98	·41	·29	·54	1·19	·58	·30
2·68	2·78	2·11	1·70	2·31	1·79	1·68	1·75
3·21	3·32	2·83	2·94	3·11	2·43	2·15	1·87
1·08	·88	1·12	1·11	·98	1·31	1·25	·80
·85	·82	·91	1·16	1·89	1·55	1·56	1·30
4·80	3·84	2·38	2·46	1·99	2·38	2·77	1·10
5·86	6·79	4·33	2·90	6·25	4·02	4·75	2·40
·85	·96	·70	·57	·51	·84	·46	0·05
3·29	3·39	2·76	·53	2·39	2·14	1·68	1·40
1·88	1·56	1·57	·90	1·60	1·37	1·38	·70
2·72	2·74	2·60	1·51	2·35	2·20	2·62	2·60
1·52	1·25	1·48	1·55	1·61	1·24	1·24	1·15
29·81	29·31	23·20	17·62	25·53	22·46	22·12	15·42

Division VII.—North Midland Counties (*continued*).							
Lincoln (*continued*).							
Burton.	Market Rasen.	Gainsborough.	Spring Gardens, Gainsboro'.	Stockwith.	Brigg.	Grimsby.	Barnetby.
3 ft. 6 in. 96 ft.	3 ft. 6 in. 100 ft.	3 ft. 6 in. 76 ft.	8 ft. 0 in. 38 ft.	3 ft. 6 in. 21 ft.	3 ft. 6 in. 16 ft.	15 ft. 0 in. 42 ft.	3 ft. 6 in. 51 ft.
in.	in.	in.	in.	in.	in.	in.	in.
·94	0·00	·19	·28	0·00	·60	1·01	·85
2·53	3·50	2·42	2·33	1·88	2·49	1·44	2·61
1·96	1·67	1·40	1·75	1·52	1·44	1·24	1·47
1·07	1·34	1·02	1·00	·82	·91	1·22	1·01
·56	2·22	·70	·66	·74	1·06	·83	·82
3·54	2·77	3·07	2·72	2·50	2·51	2·80	2·64
3·74	3·22	4·26	4·53	3·83	4·34	3·50	3·38
·53	·37	·38	·53	·49	·46	·23	·42
1·64	2·74	1·39	1·46	1·62	2·68	1·13	2·11
·94	·74	1·08	1·05	1·36	1·29	·66	1·18
2·50	3·97	2·44	2·36	2·48	3·25	3·22	3·36
1·29	1·50	1·20	1·14	1·01	1·45	·98	1·30
21·24	24·04	19·55	19·81	18·25	22·48	18·26	21·15

ENGLAND AND WALES.

Division VII.—North Midland Counties (*continued*).						
Lincoln (*continued*).		Nottingham.				
1861.	New Holland.	Highfield House.	Highfield House.	Welbeck.	Worksop.	Retford.
Height of Rain-gauge above Ground..	3 ft. 6 in.	0 ft. 0 in.	25 ft. 0 in.	4 ft. 0 in.	3 ft. 6 in.	3 ft. 6 in.
Height of Rain-gauge above Sea-level.	18 ft.	162 ft.	187 ft.	....	127 t.	52 ft.
	in.	in.	in.	in.	in.	in.
January	·37	·85	·69	·46	0·00	·30
February	2·19	2·72	2·48	2·11	3·08	2·27
March	1·56	3·43	2·84	3·03	2·61	2·17
April	1·01	1·69	1·19	1·56	1·35	1·19
May	·74	1·20	·93	1·08	1·39	·79
June	3·30	1·70	1·49	4·81	2·22	2·69
July	3·71	3·46	3·34	4·54	3·19	3·45
August	·53	·56	·54	·86	·23	·29
September	2·22	1·93	1·91	1·86	1·69	1·47
October	1·03	1·35	1·26	1·16	1·45	1·42
November	2·82	2·03	1·94	2·26	2·06	2·43
December	1·25	1·41	1·40	·43	1·14	1·26
Totals	20·73	22·33	20·01	24·16	20·41	19·73

Division VII.—North Midland Counties (*continued*).			Division VIII.—North-Western Counties.			
Derbyshire (*continued*).			Cheshire.			
1861.	Chapel-en-le-Frith.	Woodhead.	Bosley Minns.	Bosley Reservoir.	Macclesfield.	Macclesfield.
Height of Rain-gauge above Ground..	3 ft. 6 in.	3 ft. 6 in.	3 ft. 6 in.	3 ft. 6 in.	2 ft. 9 in.	3 ft. 6 in.
Height of Rain-gauge above Sea-level.	965 ft.	939 ft.	1210 ft.	590 ft.	500 ft.	539 ft.
	in.	in.	in.	in.	in.	in.
January	·29	1·20	·80	·16	·40	·14
February	3·09	6·22	2·14	1·94	1·97	1·86
March	6·53	9·83	3·90	3·15	5·72	5·13
April	1·29	2·50	1·18	1·35	1·41	1·24
May	·99	2·13	1·09	1·18	1·22	1·25
June	3·67	4·13	3·12	3·61	3·18	2·84
July	4·36	4·60	4·63	4·20	4·33	4·34
August	2·42	3·83	1·71	2·15	2·47	2·43
September	5·22	4·36	3·03	3·52	4·22	4·28
October	1·70	1·72	1·76	1·36	1·24	1·22
November	4·53	6·13	2·67	3·07	3·85	3·97
December	3·10	2·99	2·62	2·07	2·02	1·99
Totals	37·19	49·64	28·65	27·76	32·03	30·59

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ENGLAND AND WALES.

Division VII.—North Midland Counties (*continued*).

Nottingham (*cont.*).		Derbyshire.					
ast Retford.	West Retford.	Derby.	Chatsworth.	Chesterfield.	Norwood.	Combs Moss.	Combs Reservoir.
2 ft. 0 in. 50 ft.	0 ft. 6 in. 50 ft.	5 ft. 0 in. 179 ft.	6 ft. 0 in. 404 ft.	3 ft. 6 in. 248 ft.	3 ft. 6 in. 238 ft.	3 ft. 6 in. 1669 ft.	3 ft. 6 in. 710 ft.
in.	in.	in.	in.	in.	in.	in.	in.
·18	·23	·66	·47	1·06	·48	1·14	·50
2·17	2·17	2·17	4·85	4·20	3·79	3·57	4·25
2·12	2·11	3·86	4·90	3·71	3·47	6·27	8·56
1·16	1·14	1·20	1·29	1·92	1·29	·50	1·57
·79	·83	·63	1·04	·83	1·06	1·40	1·45
2·76	3·05	1·24	3·46	2·29	2·89	3·24	3·34
3·57	3·16	4·30	4·45	3·72	3·38	4·55	4·60
·32	·32	·92	1·11	·33	·56	3·10	3·50
1·52	1·67	2·16	2·81	2·01	2·26	4·32	6·22
1·34	1·33	1·26	1·39	1·65	1·23	1·66	2·02
2·35	2·01	2·15	3·51	2·09	2·34	4·08	6·22
1·28	1·29	1·46	2·04	1·67	1·40	4·50	3·41
19·56	19·31	22·01	31·32	25·48	24·15	33·33	45·64

Division VIII.—North-Western Counties (*continued*).

Cheshire (*continued*).							
Kingsley, Frodsham.	Sponds Hill, Bollington.	Whaley.	Quarry Bank.	Thelwall, Northwich.	Aqueduct, Marple.	Top Lock, Marple.	Hill End, Mottram.
0 ft. 0 in. 208 ft.	3 ft. 6 in. 1279 ft.	3 ft. 6 in. 602 ft.	0 ft. 8 in. 295 ft.	1 ft. 6 in. 96 ft.	3 ft. 6 in. 321 ft.	3 ft. 6 in. 543 ft.	3 ft. 6 in. 680 ft.
in.	in.	in.	in.	in.	in.	in.	in.
·24	·98	·72	·22	·26	·31	·20	·63
2·57	2·79	2·67	1·56	2·72	1·99	1·48	1·83
3·57	6·99	6·72	4·86	4·29	6·39	4·00	6·13
1·73	1·51	1·40	1·56	1·71	1·48	1·56	1·27
1·01	1·42	1·49	1·03	·70	1·10	·85	1·29
2·68	2·04	2·00	1·79	2·67	3·01	3·66	1·94
4·25	4·55	4·46	2·89	3·59	4·22	3·84	5·66
2·84	2·93	2·85	2·12	2·44	2·45	2·38	2·92
3·84	6·55	6·48	3·26	3·43	4·62	4·91	4·65
1·53	1·40	1·40	1·19	1·47	1·40	1·26	1·16
2·98	4·19	4·17	3·13	3·66	4·33	4·66	4·82
1·87	2·64	2·64	2·13	1·99	2·25	2·60	2·10
29·11	37·99	37·00	25·74	28·93	33·55	31·40	34·40

ENGLAND AND WALES.

Division VIII.—North-Western Counties (*continued*).

1861.		Cheshire (*continued*).		Lancashire.			
		Matley's Field, Mottram.	Newton.	Observatory, Liverpool.	The Brook, Liverpool.	Old Trafford, Manchester.	Sale, Manchest
Height of Rain-gauge above	Ground..	3 ft. 6 in.	3 ft. 6 in.	30 ft. 0 in.	2 ft. 0 in.	3 ft. 0 in.	2 ft. 3 in.
	Sea-level.	399 ft.	396 ft.	52 ft.	....	106 ft.	134 ft.
		in.	in.	in.	in.	in.	in.
January		0·00	·42	·27	·39	·39	·48
February		2·78	1·61	1·88	1·56	2·52	2·12
March		5·47	4·98	3·08	3·07	4·14	4·40
April		1·17	1·16	1·40	1·41	2·43	1·58
May		1·20	·97	·92	1·20	·74	·86
June		2·91	3·77	2·17	2·87	2·41	2·23
July		5·28	4·30	2·95	4·65	3·65	4·02
August		2·67	2·86	1·96	3·41	2·23	2·44
September		3·96	3·99	2·76	4·42	4·05	4·07
October		·98	1·23	1·53	2·42	1·23	1·14
November		4·79	4·53	2·75	3·82	3·88	3·49
December		1·95	1·98	1·48	2·06	2·07	1·75
Totals		33·16	31·80	23·15	31·28	29·74	28·58

Division VIII.—North-Western Counties (*continued*).

1861.		Lancashire (*continued*).					
		Bury.	Howick, Preston.	Fishwick, Preston.	House of Correction, Preston.	House of Correction, Preston.	Holme S Presto
Height of Rain-gauge above	Ground..	7 ft. 0 in.	0 ft. 6 in.	24 ft. 0 in.	1 ft. 1 in.	53 ft. 6 in.	1 ft. 6 in.
	Sea-level.	400 ft. ?	72 ft.	154 ft.	140 ft.	187 ft.	143 ft.
		in.	in.	in.	in.	in.	in.
January		·20	·72	·52	·67	·62	·63
February		2·65	3·97	2·64	3·11	2·96	3·72
March		3·50	4·39	4·32	4·30	3·35	4·42
April		1·75	1·35	1·12	1·23	1·03	1·31
May		·75	1·24	1·16	1·22	1·00	1·13
June		1·35	2·39	1·52	1·73	1·92	1·80
July		4·67	3·82	2·96	3·76	3·35	4·12
August		3·10	3·88	3·76	3·99	3·33	4·07
September		3·15	4·10	4·40	4·41	3·79	5·30
October		2·10	3·50	3·96	4·12	3·75	4·28
November		2·55	4·95	4·56	4·94	3·70	5·07
December		3·90	2·28	2·40	2·42	1·95	2·63
Totals		29·67	36·59	33·32	35·90	30·75	38·48

ENGLAND AND WALES.

Division VIII.—North-Western Counties (*continued*).

Lancashire (*continued*).

Market Street, Manchester.	Piccadilly, Manchester.	Fairfield.	Waterhouses, Oldham.	Bolton-le-Moors.	Belmont, Bolton-le-Moors.	Heaton, Bolton-le-Moors.	Standish, Wigan.
3 ft. 0 in. ………	46 ft. 0 in. 194 ft.	6 ft. 0 in. 312 ft.	3 ft. 6 in. 345 ft.	2 ft. 0 in. 290 ft.	0 ft. 0 in. 800 ft.	0 ft. 0 in. 500 ft.	0 ft. 0 in. 285 ft.
in.	in.	in.	in.	in.	in.	in.	in.
·26	·40	·41	·17	·78	1·20	·70	2·04
2·66	2·77	2·70	2·74	3·85	3·60	2·90	4·09
5·26	5·96	6·16	6·06	6·92	7·20	5·20	6·17
1·29	1·65	1·45	1·18	1·72	2·10	2·70	2·11
·65	·95	1·11	1·15	1·45	1·70	1·40	1·66
2·12	1·97	2·37	2·08	1·56	3·10	2·60	4·45
3·89	4·25	4·41	4·52	4·99	6·30	4·70	5·71
1·87	2·66	3·38	3·16	4·47	6·50	3·50	3·94
3·95	4·85	4·95	4·38	7·28	9·20	6·40	7·08
1·43	1·70	1·57	·88	2·43	2·40	1·90	2·80
3·91	5·14	5·05	4·62	6·12	8·30	5·20	5·08
2·04	2·13	2·20	1·85	3·34	4·10	2·70	2·50
29·33	34·43	35·76	32·79	44·91	55·70	39·90	47·63

Division VIII.—North-Western Counties (*continued*).

Lancashire (*continued*).

uth Shore, Blackpool.	Observatory, Stonyhurst.	Bleasdale, Garstang.	Caton, Lancaster.	Hest Bank, Lancaster.	Holker, Cartmel.	Cartmel.	Coniston.
1 ft. 8 in. 29 ft.	0 ft. 0 in. 381 ft.	4 ft. 6 in. 600 ft.	2 ft. 4 in. 120 ft.	2 ft. 2 in. 82 ft.	4 ft. 8 in. 155 ft.	6 ft. 1 in. 171 ft.	4 ft. 11 in. 154 ft.
in.	in.	in.	in.	in.	in.	in.	in.
1·60	1·10	·68	1·44	1·49	2·81	3·53	13·50
3·80	4·00	5·92	4·24	3·83	5·29	3·44	9·20
3·75	6·80	5·90	5·76	5·03	5·65	6·26	11·50
1·50	1·40	1·14	·74	·62	·86	·76	·30
·90	1·40	1·58	1·21	1·05	1·29	·91	2·70
1·90	2·30	2·63	2·73	2·36	2·78	3·49	4·00
3·20	5·30	7·06	4·36	3·48	5·50	4·63	11·50
3·75	6·30	7·53	6·50	5·68	7·41	6·87	12·00
3·80	5·80	6·41	4·70	4·31	5·35	3·34	10·00
2·00	3·00	4·13	2·52	4·06	3·33	3·36	5·00
5·20	8·60	8·38	7·63	6·77	7·01	7·62	17·00
2·30	3·00	3·69	2·71	2·63	2·83	3·02	5·50
33·70	49·00	55·05	44·54	41·31	50·11	47·23	102·20

ENGLAND AND WALES.

Div. VIII.—N.-W. Co. (*cont.*)		Division IX.—YORKSHIRE.				
LANCASHIRE (*continued*).		YORKSHIRE—WEST RIDING.				
1861.	Wray Castle, Windermere.	Station, Sheffield.	The Edge, Sheffield.	Broomhall Park, Sheffield.	Redmires, Sheffield.	Tickhill.
Height of Rain-gauge above Ground..	4 ft. 9 in.	3 ft. 6 in.	3 ft. 6 in.	0 ft. 4 in.	3 ft. 0 in.	0 ft. 1 in.
Height of Rain-gauge above Sea-level.	250 ft.	188 ft.	336 ft.	337 ft.	1100 ft.	61 ft.
	in.	in.	in.	in.	in.	in.
January	6·08	·67	·98	·76	·27	·59
February	8·11	4·20	5·39	5·39	5·46	2·86
March	9·96	4·44	5·15	5·20	6·65	3·19
April	1·64	2·21	2·48	2·29	3·23	1·66
May	1·29	·90	·86	·88	1·10	·83
June	3·68	1·60	2·75	2·51	3·89	2·85
July	8·76	2·89	4·23	3·69	4·40	3·75
August	9·53	·68	1·07	·95	2·06	·41
September	7·88	2·32	2·93	2·19	3·02	2·14
October	4·37	1·12	1·42	1·25	1·46	1·03
November	14·44	2·87	3·08	2·87	4·04	2·62
December	5·17	1·65	1·82	1·70	2·36	1·21
Totals	80·91	25·55	32·16	29·68	37·94	23·14

Division IX.—YORKSHIRE (*continued*).						
YORKSHIRE—WEST RIDING (*continued*).						
1861.	Wakefield.	Well Head, Halifax.	Hunter's Hill, Halifax.	Warley Moor, Halifax.	Midgeley Moor, Halifax.	Ovenden Moor, Halifax.
Height of Rain-gauge above Ground..	4 ft. 0 in.	1 ft. 0 in.	1 ft. 0 in.	1 ft. 0 in.	1 ft. 0 in.	1 ft. 0 in.
Height of Rain-gauge above Sea-level.	115 ft.	487 ft.	1250 ft.	1425 ft.	1350 ft.	1375 ft.
	in.	in.	in.	in.	in.	in.
January	·23	·19	1·80	1·40	1·90	1·50
February	3·90	3·97	4·60	5·30	5·40	5·30
March	3·56	5·24	5·10	6·10	7·40	6·60
April	1·63	1·30	·90	1·20	1·30	1·20
May	·70	·78	0·00	·10	0·00	·10
June	2·02	1·74	1·00	1·90	2·30	2·00
July	2·51	5·07	4·30	6·60	6·60	6·50
August	·78	1·52	1·80	4·40	4·70	4·10
September	2·53	3·39	4·70	5·30	5·90	5·10
October	·87	·69	·50	1·00	1·20	·90
November	2·53	5·08	6·10	8·50	9·20	9·80
December	1·04	1·82	1·90	2·20	2·80	·80
Totals	22·30	30·79	32·70	44·00	48·70	43·70

ENGLAND AND WALES.

Division IX.—Yorkshire (*continued*).

Yorkshire—West Riding (*continued*).

Dunford Bridge.	Penistone.	Carlcotes.	Standedge.	Saddleworth.	Villa, Ackworth.	Ackworth.	Longwood, Huddersfield.
3 ft. 6 in. 954 ft.	3 ft. 6 in. 717 ft.	3 ft. 6 in. 1075 ft.	2 ft. 0 in. 1150 ft.	5 ft. 0 in. 640 ft.	0 ft. 1 in. 135 ft.	....	24 ft. 0 in. ....
in.	in.	in.	in.	in.	in.	in.	in.
·40	·61	·64	1·00	·34	·53	·18	·28
5·86	4·17	4·05	3·00	2·20	3·17	2·49	3·20
10·67	5·28	9·56	9·00	3·35	2·54	2·12	5·88
2·01	1·17	1·59	1·50	1·91	1·17	1·25	1·32
1·66	·61	1·12	1·25	1·12	·87	·93	·83
2·00	2·30	2·33	3·50	1·95	1·87	1·74	2·08
5·02	3·46	5·15	5·75	4·63	3·25	2·57	3·98
3·03	·53	2·84	5·25	3·20	·73	·63	1·95
4·77	2·16	4·63	7·00	4·92	1·96	1·89	3·77
2·16	1·37	1·72	1·50	1·46	1·24	1·07	·78
7·01	3·70	6·90	7·50	5·26	2·38	2·23	4·52
3·29	1·66	3·09	3·50	2·04	1·18	1·16	1·83
47·88	27·02	43·62	49·75	32·38	20·89	18·26	30·42

Division IX.—Yorkshire (*continued*).

Yorkshire—West Riding (*continued*).

Horton Hall, Bradford.	Holbeck, Leeds.	Holbeck, Leeds.	Philosophical Hall, Leeds.	Eccup, Leeds.	Red Hall, Whin Moor.	Top of Chevin, Otley.	The Valley, Otley.
0 ft. 8 in. 496 ft.	0 ft. 0 in. 95 ft.	40 ft. 0 in. 135 ft.	40 ft. 0 in. 137 ft.	0 ft. 0 in. 340 ft.	5 ft. 0 in. 455 ft.	4 ft. 7 in. 764 ft.	0 ft. 7 in. 206 ft.
in.	in.	in.	in.	in.	in.	in.	in.
1·08	·15	1·60?	·02	·28	·73	1·15	1·72
5·08	2·89	3·25	1·56	3·46	2·36	3·38	4·57
6·50	3·60	3·25	3·42	3·76	3·32	3·78	4·59
1·41	1·17	1·15	1·48	1·04	1·18	1·23	1·12
·84	·63	·35	·76	·74	·54	·69	·63
1·90	1·47	1·10	1·79	2·46	2·27	1·75	1·51
3·63	4·92	5·05	3·94	3·42	4·04	3·38	2·67
1·13	·93	·45	....	1·25	1·35	1·80	1·26
4·43	3·05	2·70	....	3·17	3·64	3·26	3·42
·99	·93	·70	....	1·04	1·19	1·17	1·13
4·67	2·20	2·25	....	2·24	2·34	2·69	2·93
2·39	1·39	1·45	....	1·39	1·49	1·73	1·74
34·05	23·33	23·30	....	24·25	24·45	26·01	27·29

ENGLAND AND WALES.

Division IX.—YORKSHIRE (*continued*).						
	YORKSHIRE—WEST RIDING (*continued*).					YORKSHIRE E. RIDING
1861.	Ben Rhydding.	High Harrogate.	Settle.	Clapham.	Arncliffe.	Patrington
Height of Rain-gauge above Ground.. / Sea-level.	2 ft. 6 in. 500 ft.	0 ft. 6 in. 420 ft.	40 ft. 0 in. 498 ft.	5 ft. 0 in. 550 ft.	2 ft. 6 in. 750 ft.	4 ft. 8 in. 32 ft.
	in.	in.	in.	in.	in.	in.
January	·69	·90	2·10	1·62	2·16	2·00
February	1·52	3·60	5·40	4·29	5·28	1·70
March	3·90	4·80	5·12	4·95	8·93	1·22
April	1·05	1·20	·47	·64	·79	·76
May	·81	·70	·39	·73	·88	·60
June	2·09	2·43	2·20	2·61	2·60	1·64
July	3·62	3·18	4·02	4·49	6·02	3·30
August	1·48	1·70	4·05	4·37	6·63	·34
September	4·30	3·60	5·48	5·73	7·88	1·30
October	1·10	1·38	2·06	3·06	2·78	·66
November	·67	3·43	7·52	6·37	11·39	3·80
December	1·22	1·59	2·98	3·17	4·60	1·30
Totals	22·45	28·51	41·79	42·03	59·94	18·62

Division IX.—YORKSHIRE (*continued*).			Division X.—NORTHERN COUNTIES.			
	YORKSHIRE—NORTH RIDING (*continued*).		DURHAM.			
1861.	Scarborough.	Redcar.	Darlington.	Stubb House, Winston.	Durham.	Bishop-wearmouth
Height of Rain-gauge above Ground.. / Sea-level.	9 ft. 0 in. 91 ft.	2 ft. 3 in. 20 ft.	4 ft. 0 in. 140 ft.	0 ft. 9 in. 460 ft.	1 ft. 0 in. 338 ft.	30 ft. 0 in. 140 ft.
	in.	in.	in.	in.	in.	in.
January	·66	·60	1·39	·78	1·21	1·04
February	1·54	·45	6·28	2·01	2·56	1·53
March	1·77	·85	3·94	2·19	1·83	1·89
April	1·08	·37	1·43	1·51	1·55	1·00
May	·77	1·15	·65	·34	·72	·72
June	1·66	1·18	4·12	1·93	2·94	1·93
July	2·89	2·22	2·68	3·30	3·17	3·18
August	·44	·80	2·24	1·66	1·37	1·29
September	2·08	1·54	2·91	2·83	2·50	2·01
October	1·38	·40	1·28	1·25	1·27	1·01
November	2·32	2·97	3·66	5·11	4·01	3·00
December	1·38	·89	2·25	1·63	1·15	·70
Totals	17·97	13·42	32·83	24·54	24·28	19·30

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ENGLAND AND WALES.

Division IX.—Yorkshire (*continued*).

Yorkshire—East Riding (*continued*).							Yorkshire, N. Riding.
Hull.	Hull.	Holme-on-Spalding-Moor.	Wheldrake.	Middleton, Beverley.	York.	Huggate, Pocklington.	Malton.
4 ft. 0 in. 12 ft.	27 ft. 0 in. 30 ft.	7 ft. 6 in. 32 ft.	1 ft. 4 in. 40 ft.	1 ft. 0 in. 150 ft.	0 ft. 5 in. 50 ft.	0 ft. 6 in. 550 ft.	1 ft. 0 in. 80 ft.
in.	in.	in.	in.	in.	in.		in.
·94	·73	·70	·54	·96	·65	Gauge visited October 27th, 1862, and its position found most objectionable, returns therefore omitted.—G. J. S.	·90
2·09	1·90	2·15	2·29	2·50	2·42		3·25
1·72	1·49	1·82	1·91	2·16	2·20		2·22
·90	·81	·93	1·16	·88	·24		·80
·84	·51	1·04	·80	·77	·60		·94
2·41	4·84	2·28	1·68	2·30	2·27		2·58
3·41		4·70	3·39	5·00	3·03		2·90
·45	·33	·57	·77	1·03	·86		1·16
1·91	1·83	2·63	3·44	4·60	3·61		3·61
·86	·73	1·32	·68	1·00	·72		·91
3·27	2·86	2·77	2·69	3·93	2·60		3·76
1·17	1·13	1·10	1·19	1·29	1·07		1·44
19·97	17·16	22·01	20·54	26·42	20·27	....	24·47

Division X.—Northern Counties (*continued*).

Northumberland.							
hetley Hall.	Allenheads.	Allenheads.	Newcastle-on-Tyne.	Park End, Newcastle.	Bywell.	Wylam.	N. Shields.
0 ft. 8 in. 309 ft.	0 ft. 5 in. 1360 ft.	6 ft. 9 in. 1367 ft.	42 ft. 0 in. 187 ft.	0 ft. 3 in. 300 ft.	0 ft. 6 in. 87 ft.	0 ft. 4 in. 96 ft.	1 ft. 0 in. 124 ft.
in.	in.	in.	in.	in.	in.	in.	in.
·54	1·26	1·62	·60	2·64	1·42	·89	1·00
3·98	7·28	6·03	2·08	2·39	3·22	2·97	1·97
2·32	5·15	5·61	1·55	3·61	2·35	1·84	2·23
1·55	2·00	2·16	1·05	·94	1·51	1·17	1·25
1·19	1·44	1·58	·60	·53	·63	·71	1·42
3·64	2·31	2·50	2·55	1·89	3·84	2·17	3·76
4·65	4·84	5·27	2·88	2·79	3·73	3·37	2·37
1·11	4·07	4·61	1·50	3·03	1·65	1·76	1·67
2·57	5·22	5·67	1·79	3·86	2·82	2·63	2·72
1·26	2·05	2·10	·73	1·05	1·42	1·23	1·10
4·82	10·69	12·10	2·90	6·67	4·42	3·76	4·36
1·17	3·04	3·64	·55	1·67	1·43	1·04	·89
28·80	49·35	52·89	18·78	31·07	28·44	23·54	24·74

ENGLAND AND WALES.

Division X.—Northern Counties (*continued*).						
	Northumberland (*continued*).				Cumberland.	
1861.	Stamfordham.	Alnwick.	Roddam Hall, Alnwick.	Lilburn Tower, Alnwick.	The Flosh, Cleator.	Seathwaite, Borrowdale.
Height of Rain-gauge above Ground..	1 ft. 1 in.	0 ft. 6 in.	0 ft. 6 in.	6 ft. 0 in.	1 ft. 6 in.	1 ft. 0 in.
Height of Rain-gauge above Sea-level.	380 ft.	400 ft.	400 ft. ?	250 ft. ?	240 ft.	422 ft.
	in.	in.	in.	in.	in.	in.
January	·62	4·50	·73	1·14	3·11	9·88
February	1·94	2·02	2·53	2·12	4·44	18·27
March	1·58	2·09	2·77	1·70	6·49	26·08
April	1·75	2·02	2·14	2·36	·77	·82
May	·67	1·34	1·11	1·22	1·34	4·61
June	2·51	2·60	1·24	1·16	4·41	7·70
July	4·50	2·20	1·49	1·81	5·26	14·50
August	2·13	2·20	3·34	2·39	7·38	25·20
September	3·51	4·40	2·97	4·21	4·83	17·42
October	1·44	1·03	1·98	·75	3·05	9·07
November	4·51	4·27	3·66	5·35	8·78	35·41
December	1·06	1·30	2·31	1·81	4·52	13·62
Totals	26·22	29·97	26·27	26·02	54·58	182·58

Division X.—Northern Counties (*continued*).		Division XI.—Monmouthshire, Wales, and the Isles.				
Westmoreland (*continued*).		Monmouth.	Glamorgan.	Pembroke.		Cardigan.
1861.	Lancregg, Grasmere.	Chepstow.	Ystalyfera.	Pembroke Dock.	Haverfordwest.	Lampeter.
Height of Rain-gauge above Ground..	4 ft. 6 in.	1 ft. 6 in.	4 ft. 0 in.	0 ft. 0 in.	2 ft. 0 in.	5 ft. 0 in.
Height of Rain-gauge above Sea-level.	300 ft. ?	50 ft.	300 ft.	30 ft.	60 ft.	425 ft.
	in.	in.	in.	in.	in.	in.
January	6·09	2·01	2·63	3·35	3·05	1·77
February	13·39	2·94	4·78	5·45	5·27	4·90
March..................	15·30	3·68	6·51	2·00	2·55	2·77
April	1·19	·61	·26	·70	1·12	·58
May	1·64	1·49	1·40	1·06	·95	1·36
June	3·65	2·12	3·71	3·10	3·41	3·02
July	8·47	7·31	10·89	6·01	8·13	4·68
August	17·50	2·01	8·11	4·16	5·86	3·53
September	16·28	4·31	9·04	3·78	5·05	6·00
October	9·05	2·48	3·22	3·81	2·41	3·20
November	20·17	6·05	10·41	7·49	9·32	6·62
December	10·49	2·50	5·82	3·86	4·68	5·55
Totals	123·22	37·51	66·78	44·77	51·80	43·98

ENGLAND AND WALES.

Division X.—Northern Counties (*continued*).							
Cumberland (*continued*).					Westmoreland.		
Keswick.	Whinfell Hall, Vale of Lorton.	Mirehouse, Bassenthwaite.	Silloth.	Carlisle.	Kendal.	Lesketh How, Ambleside.	The How, Troutbeck.
6 ft. 3 in. 270 ft.	2 ft. 0 in. 250 ft.?	0 ft. 5 in. 300 ft.	6 ft. 0 in. 16 ft.	47 ft. 0 in. 105 ft.	4 ft. 6 in. 149 ft.	3 ft. 0 in. 200 ft.	1 ft. 8 in. 403 ft.
in.	in.	in.	in.	in.	in.	in.	in.
4·21	3·29	2·29	2·51	1·37	3·74	6·69	9·08
9·30	7·29	7·06	3·14	1·68	5·74	12·08	13·62
6·68	7·66	7·51	4·98	3·48	7·95	11·67	15·60
·91	·92	·96	·50	·60	·55	·99	1·25
·55	1·52	1·41	·87	·89	·71	1·10	·79
3·15	2·87	2·08	2·65	2·06	3·01	4·62	2·56
8·28	5·53	4·91	4·29	4·80	6·88	9·56	8·64
7·58	8·66	7·02	5·48	4·14	8·31	10·96	15·91
9·11	6·21	7·40	3·13	5·15	5·85	9·52	12·46
3·54	4·53	3·24	1·96	1·62	3·53	5·76	5·17
13·84	14·22	11·49	10·34	6·56	11·40	17·88	21·41
7·27	6·24	4·98	2·62	2·11	3·03	7·20	9·77
74·42	68·94	60·35	42·47	34·46	60·70	98·03	116·26

ENGLAND AND WALES.

SCOTLAND.

Division XI.—Monmouthshire, Wales, and the Isles (*continued*).					Division XII.—Southern Counties.		
Anglesey.	Carnarvon.	Flint.	Islands.		Wigtown, &c.		
Llandyfrydog.	Llandudno.	Hawarden.	Guernsey.	St. Mary's, Scilly.	South Cairn, Stranraer.	Cargen.	Dumfries.
2 ft. 0 in. 92 ft.	0 ft. 4 in. 20 ft.?	0 ft. 0 in. 260 ft.	12 ft. 0 in. 200 ft.	1 ft. 0 in. 30 ft.	0 ft. 4 in. 210 ft.	0 ft. 3 in. 80 ft.	0 ft. 5 in. 63 ft.
in.	in.	in.	in.	in.	in.	in.	in.
2·14	1·20	·20	1·24	·89	3·75	2·29	3·90
4·19	3·00	1·81	3·48	4·49	3·20	4·47	4·05
3·78	2·80	1·85	3·35	1·67	5·75	5·06	5·30
1·03	1·30	1·26	·37	1·83	1·03	·77	·65
·85	1·30	·42	1·65	·82	1·30	·74	·75
3·56	2·40	3·08	2·49	2·16	2·90	3·08	2·90
4·55	4·30	3·28	2·68	4·29	6·15	4·11	3·95
5·64	2·50	1·31	·85	1·56	7·00	6·09	7·58
4·60	2·50	2·76	3·66	2·41	5·10	4·37	4·00
3·13	2·00	1·59	1·19	1·06	3·55	3·74	3·75
7·38	5·30	2·44	7·83	3·30	5·05	5·78	6·50
3·60	2·40	1·82	2·43	3·05	3·25	3·75	3·55
44·45	31·00	21·82	31·22	27·53	48·03	44·25	46·88

SCOTLAND.

Div. XII.—Southern Counties (*cont.*).			Div. XIII.—South-Eastern Counties.			
Wigtown, &c. (*continued*).			Selkirk.	Peebles.	Berwick.	
1861.	Drumlanrig.	Wanlockhead.	Bowhill.	Stobo Castle.	Milne Graden.	Thirlestane.
Height of Rain-gauge above Ground..	....	0 ft. 4 in.	11 ft. 0 in.	0 ft. 2 in.	....	....
Sea-level.	186 ft.?	1330 ft.	537 ft.	600 ft.	100 ft.?	558 ft.?
	in.	in.	in.	in.	in.	in.
January	5·60	7·27	2·38	1·00	·40	1·70
February	5·20	6·98	2·81	2·00	2·00	2·10
March	6·00	8·42	3·45	2·30	3·00	2·85
April	·60	·39	1·23	·40	1·50	1·50
May	1·00	·86	·60	·50	·80	·80
June	3·00	3·54	3·06	2·70	3·10	1·25
July	4·50	7·54	5·67	5·30	4·10	4·65
August	8·00	10·09	3·53	3·30	2·60	3·25
September	7·50	8·08	3·37	3·00	4·10	4·25
October	5·00	8·54	4·14	1·40	·60	1·20
November	7·50	10·36	2·51	4·60	4·90	6·10
December	5·50	9·12	3·46	1·40	2·30	1·70
Totals	59·40	81·19	36·21	27·90	29·40	31·35

Division XIII.—South-Eastern Counties (*cont.*).				Division XIV.—South-Western Counties.		
Edinburgh (*continued*).				Lanark.		
1861.	Inveresk, Musselburgh.	Edinburgh.	Edinburgh.	Douglas Castle.	Auchinraith.	Bothwell Castle.
Height of Rain-gauge above Ground..	3 ft. 0 in.	7 ft. 0 in.	78 ft. 0 in.	0 ft. 0 in.	4 ft. 9 in.	18 ft. 0 in.
Sea-level.	60 ft.	200 ft.	363 ft.	780 ft.	150 ft.	147 ft.
	in.	in.	in.	in.	in.	in.
January	·86	·31	·31	1·97	2·48	1·53
February	1·76	·21	·79	4·89	2·90	2·52
March	2·08	2·10	1·02	7·94	4·63	4·17
April	2·11	1·65	·92	1·16	·36	·55
May	·68	·55	·02	1·68	·62	·60
June	2·98	2·73	1·60	3·20	1·77	2·49
July	3·23	3·09	2·51	6·42	4·62	3·81
August	2·98	3·42	3·07	7·13	5·10	2·11
September	4·59	4·30	4·26	7·32	4·00	1·25
October	1·54	1·54	1·27	4·23	3·12	·86
November	4·75	4·31	2·38	10·25	3·24	3·65
December	·95	·67	·67	4·90	2·10	1·90
Totals	28·51	24·88	18·82	61·09	34·94	25·44

SCOTLAND.

Division XIII.—South-Eastern Counties (*continued*).

Berwick *ontinued*).	Haddington.				Edinburgh.		
Mungo's Walls.	Yester.	Smeaton.	East Linton.	Thurston, Dunbar.	Harlaw, Edinburgh.	Reservoir, North Esk.	Glencorse.
0 ft. 4 in. 267 ft.	0 ft. 6 in. 420 ft.	13 ft. 6 in, 100 ft.	0 ft. 3 in. 90 ft.	3 ft. 0 in. 320 ft.	0 ft. 6 in. 770 ft.	0 ft. 6 in. 1150 ft.	0 ft. 6 in. 680 ft.
in.	in.	in.	in.	in.	in.	in.	in.
1·56	1.15	1·23	1·68	·50	1·50	2·28	2·30
2·02	1·80	·57	·77	1·60	2·90	2·50	2·75
2·48	1·10	1·88	1·94	1·40	4·10	3·51	3·50
1·92	4·00	1·49	2·20	2·40	2·50	1·55	2·25
·95	·80	·87	1·18	·90	1·00	·70	·85
2·62	2·60	1·78	2·04	2·80	3·10	2·35	2·65
3·08	3·95	3·51	4·23	3·70	4·50	4·43	4·20
2·40	3·00	3·08	2·93	2·10	4·50	5·35	4·00
3·00	5·05	3·09	3·21	3·20	5·50	5·10	4·50
·91	1·80	1·55	1·14	·50	2·20	2·20	1·80
5·86	5·80	4·22	5·21	5·70	6·60	8·30	8·00
1·57	2·35	·70	·66	1·00	1·90	2·00	1·30
28·37	33·40	23·97	27·19	25·80	40·30	40·27	38·10

Division XIV.—South-Western Counties (*continued*).

Lanark (*continued*).				Ayr.			Renfrew.
Baillieston.	Hillend House, Shotts.	Observatory, Glasgow.	Glasgow.	Auchendrane House, Ayr.	Largs.	Brisbane Glen.	Nither Place, Mearns.
0 ft. 3 in. 230 ft.	7 ft. 0 in. 620 ft.	0 ft. 0 in. 200 ft.	56 ft. 0 in. 160 ft.	2 ft. 3 in. 94 ft.	0 ft. 6 in. 30 ft. ?	0 ft. 0 in. 125 ft.	1 ft. 2 in. 350 ft.
in.	in.	in.	in.	in.	in.	in.	in.
3·24	2·74	6·71	2·05	4·87	4·30	5·60	3·50
3·36	2·74	2·67	2·27	3·13	3·10	3·50	4·50
4·95	3·79	5·56	3·90	6·36	6·60	6·85	3·70
·84	1·05	·63	·39	·61	·50	·60	0·00
1·06	·78	1·49	·68	1·37	1·60	1·90	·50
3·22	2·67	3·16	2·02	3·84	3·30	3·60	2·60
7·30	3·75	5·71	3·66	2·73	3·50	3·90	3·50
7·55	7·05	8·33	5·43	6·40	11·20	12·70	5·80
5·07	5·22	5·23	3·89	4·98	5·50	6·00	5·50
4·18	3·61	3·42	3·04	3·80	4·90	5·15	4·10
6·31	4·80	5·96	3·84	7·72	7·20	8·10	9·00
2·96	1·75	2·24	2·03	3·40	4·10	4·10	4·00
50·04	39·95	51·11	33·20	49·21	55·80	62·00	46·70

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	Division XIV.—South-Western Counties (*continued*).				Div. XV.—West Midland Counties.	
	Renfrew (*continued*).				Stirling.	Bute
1861.	Kilbarchan.	Locherfield, Paisley.	Fergualie House, Paisley.	Greenock.	Polmaise Gardens.	Isle of Cumbra
Height of Rain-gauge above Ground..	1 ft. 0 in.	3 ft. 6 in.	0 ft. 3 in.	0 ft. 6 in.	0 ft. 2 in.	4 ft. 6 in.
Height of Rain-gauge above Sea-level.	350 ft.	....	85 ft.	64 ft.	8 ft.	50 ft.
	in.	in.	in.	in.	in.	in.
January	10·00	7·80	6·50	6·00	3·50	4·30
February	5·70	3·40	6·00	4·90	4·00	2·20
March	9·27	3·40	9·05	9·62	4·90	5·70
April	·80	·50	1·37	·45	·50	·20
May	1·00	·40	1·20	1·67	1·00	1·50
June	4·87	1·70	2·91	3·90	2·00	2·50
July	5·35	3·40	3·65	3·85	5·10	4·00
August	13·38	14·10	10·50	11·15	7·60	9·30
September	6·30	5·70	5·85	7·10	5·00	4·80
October	5·90	4·70	5·15	5·85	4·30	4·30
November	11·25	6·90	10·36	9·30	5·70	5·10
December	5·00	3·90	4·25	5·35	3·00	3·30
Totals	78·82	55·90	66·79	69·14	46·60	47·20

	Division XV.—West Midland Counties (*continued*).			Division XVI.—East Midlan Counties.		
	Argyll (*continued*).			Kinross.	Fife.	
1861.	Isle of Easdale.	Oban.	Torosay, Isle of Mull.	Loch Leven.	Balfour.	Nookto
Height of Rain-gauge above Ground..	0 ft. 6 in.	0 ft. 0 in.	1 ft. 0 in.	....	0 ft. 4 in.	0 ft. 6 in.
Height of Rain-gauge above Sea-level.	25 ft.	10 ft.	18 ft.	....	127 ft.	80 ft.
	in.	in.	in.	in.	in.	in.
January	5·90	7·00	9·60	2·60	1·10	1·29
February	3·40	6·73	9·80	3·00	1·16	1·81
March	8·30	10·55	13·80	2·80	·93	2·12
April	·50	·50	·40	1·00	·29	·88
May	2·90	3·05	2·90	1·50	·75	1·49
June	3·30	2·90	4·40	2·00	·91	1·55
July	1·30	3·65	4·80	3·10	1·46	2·41
August	8·90	11·35	14·30	6·00	5·31	5·46
September	5·80	6·85	10·20	5·60	5·77	4·73
October	4·80	5·70	7·10	2·20	2·14	2·05
November	7·90	8·50	10·80	5·70	5·39	5·03
December	2·50	5·20	7·90	1·80	1·55	1·60
Totals	55·50	71·98	96·00	37·30	26·76	30·42

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SCOTLAND.

Division XV.—West Midland Counties (*continued*).

Bute (*continued*).	Argyll.						
Rothesay.	Castle Toward.	Hafton Dunoon.	Otter House.	Kilmory, Lochgilphead.	Callton Mór.	Kilmartin.	Inverary Castle.
10 ft. 0 in. 40 ft.	4 ft. 0 in. 80 ft. ?	4 ft. 0 in. 40 ft.	0 ft. 6 in. 130 ft.	4 ft. 6 in. 100 ft. ?	4 ft. 6 in. 65 ft.	4 ft. 4 in. 64 ft.	0 ft. 0 in. 30 ft.
in.	in.	in.	in.	in.	in.	in.	in.
5·00	6·64	9·67	6·05	3·82	3·02	5·20	7·10
3·30	4·81	6·43	3·42	3·97	2·79	3·00	5·20
6·30	7·84	11·96	7·66	7·19	7·29	7·60	3·30
·20	·58	·39	·51	·36	·56	·10	3·10
1·70	2·05	1·79	1·99	2·24	3·08	4·00	5·20
3·50	3·61	3·87	4·23	2·40	2·71	3·40	1·00
4·10	4·19	3·32	3·61	4·58	3·63	3·70	6·30
10·50	12·21	15·06	9·50	10·87	10·25	12·70	16·00
6·30	6·60	6·93	8·61	8·11	7·08	7·60	6·20
5·20	5·69	7·65	6·74	5·25	5·37	5·80	6·10
6·10	6·74	8·93	6·50	6·62	6·37	6·00	12·00
4·20	4·38	6·14	5·02	3·88	3·68	4·40	7·10
56·40	65·34	82·14	63·84	59·29	55·83	63·50	78·60

Division XVI.—East Midland Counties (*continued*).

Fife (*continued*).	Perth.						
Pittenweem.	Aberfoyle.	Ledard.	Kippenross, Dunblane.	Deanston.	Loch Dhu.	Ben Lomond.	Loch Drunkie.
3 ft. 0 in. 75 ft.	0 ft. 6 in. 60 ft.	0 ft. 6 in. 1500 ft.	0 ft. 4 in. 100 ft.	0 ft. 0 in. 120 ft. ?	0 ft. 6 in. 325 ft.	0 ft. 6 in. 1800 ft.	0 ft. 6 in. 420 ft.
in.	in.	in.	in.	in.	in.	in.	in.
1·73	8·00	8·50	2·55	3·10	7·80	8·50	7·30
1·76	6·30	9·90	2·40	2·80	9·70	8·70	5·80
1·62	8·60	5·70	4·30	4·80	12·70	8·50	6·80
1·12	·40	·50	·75	·40	·60	·30	·10
·74	·70	·60	·60	·70	·90	1·60	1·20
1·78	4·30	7·80	2·20	2·60	5·20	6·70	3·70
2·39	4·00	6·70	5·70	5·10	5·40	8·50	4·30
5·48	11·60	20·20	7·10	8·00	14·70	18·10	12·40
4·91	6·20	13·40	4·45	5·10	9·20	12·20	6·30
2·00	6·10	12·50	3·15	4·00	8·90	12·30	7·00
4·14	10·50	7·90	5·40	5·80	11·10	12·20	11·40
·78	4·90	9·40	3·20	2·65	7·00	2·30	5·40
28·45	71·60	103·10	41·80	45·05	93·20	99·90	71·70

SCOTLAND.

Division XVI.—East Midland Counties (*continued*).

PERTH (*continued*).

1861.		[illegible]	Bridge of Turk.	Lanrick Castle.	Loch Katrine.	Leny, Callander.	Between Glen Finlas and Ben Ledi.
Height of Rain-gauge above	Ground .. Sea-level.	[illegible] ft. 6 in. [illegible] ft.	[illegible] ft. 6 in. 270 ft.	[illegible] ft. 0 in. [illegible] ft.	0 ft. 6 in. [illegible] ft.	0 ft. 4 in. 335 ft.	0 ft. 6 in. 1800 ft.
		in.	in.	in.	in.	in.	in.
January		[illegible]	[illegible]	[illegible]	8·00	7·50	5·00
February		[illegible]	[illegible]	[illegible]	8·50	7·30	5·80
March		8·80	[illegible]	[illegible]	[illegible]	5·80	5·70
April		[illegible]	[illegible]	[illegible]	·40	0·00	·80
May		[illegible]	[illegible]	[illegible]	·90	·60	·70
June		[illegible]	[illegible]	2·85	[illegible]	3·20	3·80
July		[illegible]	[illegible]	[illegible]	[illegible]	8·30	5·40
August		12·70	[illegible]	[illegible]	14·50	10·50	15·00
September		[illegible]	[illegible]	[illegible]	10·10	8·00	8·40
October		[illegible]	[illegible]	[illegible]	8·70	6·30	7·90
November		8·40	10·00	[illegible]	3·40	9·40	7·60
December		[illegible]	[illegible]	2·80	[illegible]	5·50	4·30
Totals		[illegible]	[illegible]	[illegible]	89·20	72·40	70·40

Division XVI.—East Midland Counties (*continued*).

		PERTH (*continued*).				FORFAR.	
1861.		Stanley.	Belmont Meigle.	Taymouth.	Dundee.	Barry.	Craigton
Height of Rain-gauge above	Ground .. Sea-level.	1 ft. 0 in. 200 ft.	0 ft. 6 in. 300 ft.	.... 372 ft. ?	0 ft. 0 in. 60 ft.	0 ft. 3 in. 35 ft.	0 ft. 0 in. 440 ft.
		in.	in.	in.	in.	in.	in.
January		2·15	2·40	3·80	1·51	1·40	3·43
February		2·60	2·50	4·50	1·60	1·83	3·37
March		2·97	2·30	5·00	1·80	2·40	3·00
April		·20	·40	·50	·60	[illegible]	·80
May		2·20	·90	·20	1·60	1·10	1·10
June		1·70	2·20	3·40	1·80	1·69	2·13
July		4·48	3·50	2·50	2·90	[illegible]	2·30
August		5·42	4·70	5·20	4·90	4·49	4·53
September		4·50	5·30	4·00	4·85	3·51	5·10
October		2·61	2·10	3·20	2·15	[illegible]	[illegible]
November		4·10	3·60	5·20	3·40	[illegible]	4·25
December		1·65	2·20	3·20	1·60	[illegible]	2·05
Totals		34·58	32·10	40·70	28·71	[illegible]	34·93

SCOTLAND.

Division XVI.—East Midland Counties (*continued*).							
Perth (*continued*).							
Glengyle.	Auchterarder House.	Stronvar, Loch Earn Head.	Colquhalzie House.	Trinity Gask.	Early Bank, Perth.	Socne Palace.	Tyndrum Mines.
0 ft. 6 in. 380 ft.	2 ft. 0 in. 150 ft.	0 ft. 3 in. 460 ft.	0 ft. 5 in. 60 ft.?	0 ft. 1 in. 135 ft.	0 ft. 3 in. 66 ft.	2 ft. 6 in. 80 ft.?	0 ft. 3 in. 792 ft.
in.	in.	in.	in.	in.	in.	in.	in,
11·10	1·25	6·15	4·20	5·20	1·90	2·00	15·40
11·80	2·27	11·20	4·48	2·85	1·72	2·32	16·90
15·20	2·37	11·90	4·28	2·80	3·29	2·63	26·60
1·30	1·29	·70	·65	·90	·86	·36	0·00
2·10	·95	1·20	1·10	·90	1·69	1·60	2·20
5·00	2·33	4·20	2·28	2·20	2·37	2·11	3·20
5·60	4·19	4·65	4·50	3·40	3·96	3·56	7·10
17·20	5·89	12·85	6·47	5·80	5·47	4·90	17·10
12·00	4·49	8·50	4·40	4·80	5·24	4·48	9·50
10·30	2·15	8·40	3·28	2·60	2·34	2·12	11·40
13·10	3·55	11·20	6·40	4·85	5·10	3·50	13·90
7·80	2·25	7·70	2·30	1·90	2·14	1·55	9·90
112·50	32·98	88·65	44·34	38·20	36·08	31·13	133·20

Division XVI.—East Midland Counties (*continued*).						Div. XVII.—North-Eastern Counties.	
Forfar (*continued*).						Kincardine.	
Kettins.	Hillhead.	Seichen.	Arbroath.	Montrose.	Montrose Museum.	The Burn, Brechin.	Balnakettle, Fettercairn.
1 ft. 0 in. 218 ft.	0 ft. 0 in. 500 ft.	0 ft. 0 in. 550 ft.	2 ft. 0 in. 65 ft.	2 ft. 6 in. 21 ft.	0 ft. 3 in. 8 ft.	0 ft. 6 in. 210 ft.	0 ft. 3 in. 450 ft.
in.	in.	in.	in.	in.	in.	in.	in.
1·23	3·23	3·30	1·75	·45	1·10	2·70	2·31
2·80	3·19	3·25	1·72	1·45	·73	3·00	2·76
2·70	3·16	3·40	1·93	2·10	1·35	2·60	2·58
·74	·87	1·00	1·35	·78	·80	·50	·80
1·61	1·03	1·07	1·25	1·28	1·25	2·20	3·55
2·28	2·09	2·33	2·53	2·04	1·87	3·00	2·50
4·00	2·76	2·85	2·56	2·11	2·48	3·00	3·77
4·76	4·67	4·70	4·74	4·38	4·55	6·90	6·59
4·73	5·20	5·33	4·23	3·86	3·70	4·90	5·14
2·01	3·00	3·05	1·98	1·59	·95	4·00	4·15
3·74	4·30	4·50	3·51	3·46	3·35	4·80	7·33
1·69	2·05	2·10	2·11	2·33	1·90	3·20	3·10
32·29	35·55	36·88	29·66	25·83	24·03	40·80	44·58

SCOTLAND.

Division XVII.—North-Eastern Counties (*continued*).

	Kincardine (*continued*).			Aberdeen.		
1861.	Bogmuir, Fettercairn.	Strachan, Banchory.	Banchory, Aberdeen.	Braemar.	Aberdeen.	Castle Newe
Height of Rain-gauge above Ground	0 ft. 3 in.	1 ft. 6 in.	0 ft. 4 in.	4 ft. 0 in.	0 ft. 4 in.	1 ft. 0 in.
Height of Rain-gauge above Sea-level	200 ft.	200 ft.	95 ft.	1110 ft.	100 ft.	915 ft.
	in.	in.	in.	in.	in.	in.
January	2·40	1·12	1·50	1·07	1·50	1·17
February	2·20	2·47	1·30	2·45	1·90	2·19
March	2·30	2·65	3·50	2·80	2·75	2·48
April	·60	1·42	·80	1·36	1·12	1·87
May	2·00	2·93	·70	·90	1·80	3·05
June	2·60	2·51	3·20	4·36	2·25	2·93
July	2·70	2·24	2·70	3·82	2·35	2·66
August	6·50	5·03	3·60	4·53	4·50	5·10
September	3·80	4·10	4·30	3·84	4·00	5·54
October	2·80	2·20	1·60	2·17	1·70	2·83
November	4·70	2·00	4·30	4·54	4·85	8·04
December	3·00	2·76	2·30	2·96	2·25	1·20
Totals	35·60	31·43	29·80	34·80	30·97	39·06

SCOTLAND. IRELAND.

Division XIX.—Northern Counties (*continued*). Division XX. Ireland.

	Sutherland (*continued*).	Orkney.		Shetland.	Cork.	Kerry.
1861.	Scourie.	Balfour, Kirkwall.	Sandwick.	Bressay.	Royal Institution, Cork.	Valen
Height of Rain-gauge above Ground	0 ft. 2 in.	0 ft. 6 in.	2 ft. 0 in.	0 ft. 9 in.	50 ft. 0 in.	1 ft. 0 in.
Height of Rain-gauge above Sea-level	20 ft.	50 ft. ?	78 ft.	20 ft.	80 ft.	50 ft.
	in.	in.	in.	in.	in.	in.
January	3·55	1·30	2·12	2·80	3·65	7·52
February	2·80	·50	1·43	3·20	5·13	5·84
March	6·50	3·40	4·71	8·10	1·99	4·73
April	·70	·50	1·02	·60	1·78	1·64
May	3·40	2·20	2·02	2·00	·02	1·35
June	1·50	·50	·78	·35	3·51	3·77
July	3·40	2·60	3·40	3·10	3·77	6·80
August	7·50	8·10	6·75	5·50	3·82	10·88
September	4·40	3·00	2·97	4·70	4·45	11·79
October	2·60	4·00	6·01	2·50	4·94	6·25
November	10·70	5·40	7·29	4·50	2·84	6·70
December	3·80	1·60	2·68	3·80	2·38	5·13
Totals	50·85	33·10	41·18	41·15	38·28	72·40

SCOTLAND.

Division XVIII.—North-Western Counties.							Div. XIX. N. Cos.
Ross.		Inverness.					Sutherland.
Stornoway, Isle of Lewes.	Bernera, Isle of Lewes.	Beaufort Castle.	Culloden House.	Portree, Isle of Skye.	Raasay House.	Loch Maddy, North Uist.	Dunrobin, Castle.
0 ft. 3 in. 70 ft.	0 ft. 6 in. 15 ft.	4 ft. 6 in. 40 ft.	3 ft. 0 in. 104 ft.	0 ft. 1 in. 60 ft.	4 ft. 0 in. 80 ft.	3 ft. 0 in. 20 ft. ?	0 ft. 4 in. 6 ft.
in.	in.	in.	in.	in.	in.	in.	in.
2.85	2.60	1.63	1.42	13.15	6.40	3.95	1.85
5.39	2.74	1.48	.80	15.43	9.00	3.20	1.65
7.61	4.96	5.15	2.53	20.35	11.05	7.70	3.52
.91	.90	.79	1.19	.78	.55	.15	.35
2.72	1.53	.39	1.08	5.04	3.20	2.80	.85
2.08	2.18	3.92	2.77	3.14	3.45	1.60	.45
4.56	5.80	2.82	4.35	9.97	6.05	3.05	3.55
8.14	9.80	3.54	2.99	15.21	10.40	10.60	3.20
6.33	7.90	4.14	5.89	12.85	10.05	8.80	4.50
3.92	5.60	1.01	1.24	8.51	6.85	4.65	1.38
7.61	6.20	7.87	5.64	22.16	10.20	7.60	5.05
5.95	10.70	2.17	1.51	12.45	9.20	6.30	1.10
58.07	60.91	34.91	31.41	139.04	86.40	60.40	27.45

IRELAND.

Division XX. (*continued*).							
Waterford.			Limerick.	Clare.		Queen's Co.	Wicklow.
Waterford.	Portlaw.	Rath-culliheen.	Limerick.	Killaloe.	Killaloe.	Portarlington.	Fassaroe, Bray.
4 ft. 0 in. 60 ft.	20 ft. 0 in. 50 ft.	1 ft. 6 in. 135 ft.	....	0 ft. 5 in. 123 ft.	5 ft. 0 in. 128 ft.	9 ft. 0 in. 245 ft.	3 ft. 0 in. 250 ft.
in.	in.	in.	in.	in.	in.	in.	in.
3.62	4.36	3.76	1.75	2.15	2.11	1.70	4.37
3.02	4.37	2.94	2.40	3.51	3.36	1.90	10.42
3.15	3.85	2.13	4.94	7.22	6.65	3.52	5.54
2.44	2.31	1.80	.65	1.16	1.12	.79	2.37
.39	.48	.28	.42	.50	.51	.29	.17
3.82	5.03	3.51	3.76	4.23	4.21	3.38	2.80
7.44	6.85	6.55	7.90	6.85	6.51	7.56	5.77
4.44	4.52	3.45	6.85	8.83	8.55	4.64	3.53
5.65	6.10	5.16	7.45	7.60	7.57	4.70	4.97
3.58	4.08	3.44	2.97	3.45	3.41	3.38	3.11
2.50	3.30	1.85	3.03	5.57	5.25	3.07	4.76
3.78	4.06	3.92	2.20	2.67	2.59	1.77	3.19
43.83	49.31	38.79	44.32	53.74	51.84	36.70	51.00

IRELAND.

Division XX. (*continued*).

	Galway.	Dublin.			
1861.	Queen's College, Galway.	Black Rock, Dublin.	Dublin.	Glasnevin, Dublin.	Monkstown.
Height of Rain-gauge above Ground ..	6 ft. 0 in.	28 ft. 0 in.	6 ft. 6 in.	6 ft. 0 in.	0 ft. 6 in.
Height of Rain-gauge above Sea-level.	25 ft.	96 ft.	166 ft.	65 ft.	90 ft.
	in.	in.	in.	in.	in.
January	3·24	1·31	1·70	2·15	2·15
February	4·58	3·23	2·60	2·99	3·77
March	6·89	3·05	3·11	3·05	3·17
April	1·22	1·23	1·39	1·50	1·46
May	1·09	·50	·58	·15	·33
June	2·79	2·60	2·73	2·99	3·13
July	6·41	3·10	4·92	4·96	4·99
August	8·49	1·24	3·16	2·85	2·82
September	10·38	3·27	2·96	3·62	3·96
October	3·91	1·65	1·74	2·06	1·97
November	5·85	2·40	1·58	2·92	2·50
December	3·77	1·09	1·02	·92	1·64
Totals	58·62	24·67	27·49	30·16	31·89

Division XX. (*continued*).

	Dublin (*continued*).	Sligo.	Armagh.	Down.	
1861.	Monkstown.	Observatory, Markree.	Observatory, Armagh.	Queen's College, Belfast.	Linen Hall, Belfast.
Height of Rain-gauge above Ground ..	90 ft. 0 in.	16 ft. 3 in.	36 ft. 0 in.	9 ft. 9 in.	4 ft. 0 in.
Height of Rain-gauge above Sea-level.	190 ft.	145 ft.	247 ft.	58 ft.	12 ft.
	in.	in.	in.	in.	in.
January	1·26	2·56	2·71	2·45	3·14
February	1·52	1·88	2·21	1·88	2·16
March	1·92	5·87	5·74	4·26	4·99
April	1·16	·44	1·07	·82	·97
May	·26	1·62	·36	·28	·38
June	2·88	4·39	4·73	1·74	2·95
July	3·22	5·29	4·88	4·56	4·48
August	2·23	6·88	6·29	5·19	5·05
September	3·00	6·42	4·50	4·38	4·48
October	1·33	2·97	2·71	2·71	2·85
November	1·41	6·16	5·39	3·66	3·83
December	·82	2·68	2·61	2·09	2·18
Totals	21·01	47·16	43·20	34·02	37·41

Note.—In the preceding Tables the height of the gauges is occasionally differently stated in 1860 and 1861; this must not be supposed to indicate change of position; the apparent discrepancy arises from the observers having reconsidered their estimates when filling up the returns for the second year. (See also p. 294.)

UNIVERSITY OF CALIFORNIA

On Thermometric Observations in the Alps.

By J. Ball, *M.R.I.A., F.L.S., &c.*

At the Meeting of the British Association at Oxford in 1860, the writer laid before the Section of Mathematics and Physics a plan for the systematic observation of temperature in the chain of the Alps, and other mountain countries, in which several members of the Alpine Club had been induced to join.

Thermometers of uniform construction had been prepared for the purpose by one of our best makers, Mr. Casella, and forms were printed with the object of securing as far as possible a uniform and complete record of such observations as should be procured.

The conditions under which these observations were to be made, and the fact that most of the observers were not professed men of science, made it indispensable to limit the plan so as to include only such objects as might be accomplished without much expenditure of time and labour, and by means of very light and portable instruments.

Four objects were suggested for inquiry:—

1st. The determination of the minimum temperature on or near to the higher peaks of the Alps, and other mountains, by means of self-registering instruments fixed in suitable positions.

2nd. To obtain comparative observations of the effects of the radiant heat of the sun upon black-bulb thermometers.

3rd. To trace the propagation of disturbances of temperature throughout a mountain district by the multiplication of observations at a number of different points.

4th. Observations on the temperature of the surface, and the upper layers of the soil, at great elevations.

Unexpected circumstances have prevented the writer from visiting the Alps during the last two years, and have very much restricted his opportunities for carrying out his own share of the work; and however moderate the expectations were which he had formed, the difficulties in the way of obtaining definite results have proved to be even greater than he anticipated; so that the plan has proved to be in some respects a complete failure, while in others a limited degree of success has attended it.

1. In regard to the observations obtained by placing minimum thermometers at great heights, the principal share of merit in whatever has been accomplished is due to Mr. F. F. Tuckett, of Bristol, who is well known as a very active and successful mountaineer, and a careful observer. He has placed a considerable number of instruments at heights ranging from 7000 to 14,000 feet, and has collected and arranged the observations made by various travellers upon the instruments so deposited by himself or by others.

The following is a summary of the work done, and the results obtained, with which the writer has been favoured by Mr. Tuckett:—

"Having been requested by the Committee of the Alpine Club to undertake the registration of such data as might result from the exposure of registering-thermometers on the loftiest summits of the Alps, I am able to supply the following brief account of what has been effected.

"The conditions of success were (1) the cooperation of as large a number as possible of our mountaineers; (2) correctness and uniformity in the instruments employed; (3) a judicious exposure which should secure them alike from the influence of radiation and the protective effect of heavy falls of snow, especially in winter; and (4) some mode of firm attachment which

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would prevent their either being carried away bodily, or the index from being disturbed by unavoidable wind or still more provoking curiosity. As to the first point, I have gratefully to acknowledge the assistance of a large number of our best mountaineers, who have either deposited instruments themselves, or sent reports of the readings of those already placed. Thanks to their united efforts, about thirty minimum thermometers have been exposed at altitudes of from 7150 to 15,784 feet over a wide tract of country, extending from the summits of the Viso, Grand Pelvoux, to the Marmolata in the Southern Tyrol.

"(2) The *correctness* of the instruments was, as far as possible, secured by entrusting their construction to Mr. L. P. Casella, one of our best makers, and their *uniformity* by the adoption of a definite pattern. At first, in the absence of a good mercurial minimum capable of acting in a horizontal position, and in the uncertainty as to the sufficiency of the range of mercury, the ordinary spirit- or Rutherford's thermometer was adopted; but experience has in the great majority of cases demonstrated its inefficiency, and in consequence all the instruments deposited during the past summer and autumn, four in number, have been mercurial, of Casella's last patent construction.

"(3) The question of exposure has not been solved as satisfactorily as could be desired, and this failure has I fear destroyed much of the value of the results obtained. In the first place, the process of attaching a thermometer to a bare rock at great elevations, often in a keen frost and chilling wind, is by no means so easy as the enthusiastic meteorologist may suppose; and without discussing here the various precautions which ought to be, and perhaps might be, adopted in some exceptional cases, I would venture to express an opinion that a well-constructed cairn of sufficient elevation, so placed as to prevent its being buried by winter snows, is the simplest and most efficient means of protecting the thermometer from the most serious causes of disturbance. When, at least, this plan has been adopted, the readings of the instruments have appeared trustworthy, and in almost all other cases sadly the reverse. By this means also they are more screened from inquisitive observation, and may better escape the pilfering propensities of an inferior order of guides, whom we probably have to thank for the disappearance of one at least fixed very securely by the writer on the Aiguille du Goûté.

"A large proportion of the Rutherford minimums have become perfectly useless from the division of the column, and it is this fact, coupled with a belief that the lowest temperature of winter on the loftiest summits rarely exceeds —40° Cent. (the freezing-point of mercury), which has led to their abandonment and the substitution of the mercurial construction. From some recent experiments, consisting in the alternate exposure of spirit-minimums to varying temperatures, I am disposed to attribute the separation of the column to this cause, which, if due precautions are not observed in placing the instrument, must be especially energetic at great altitudes.

"Unless the thermometer can be protected from the influence of radiation at night, or the respectively cooling and warming effects of a thin or thick layer of snow, variations from the true temperature of the air, amounting (as shown by M. Martins) to 10° or 12° Cent. (18° to 22° Fahr.), may be produced, and the reading utterly vitiated for purposes of comparison. Besides, if imperfectly shielded from radiation, it will probably be more or less subjected to the direct action of the solar rays, and thus be exposed to temperatures varying within twenty-four hours by as much as 55° C. (100° Fahr.). My experiments show that a much more limited range than this suffices to produce a 'solution of continuity' in the column of spirit, which has acquired amongst our mountaineers the expressive name of the 'bubble complaint.'

"In one instance an observer, whose accuracy I have no reason to doubt, informs me that he could detect *no trace whatever* of spirit, nor any indication of fracture in the glass by which it could have escaped. The index lay 'high and dry' at the bottom of the bulb. This extraordinary result he attributes to 'a sort of volatilization of the contained spirit;' and though it seems difficult to understand how it could have taken place to the extent mentioned, there is little doubt that vaporization of the contained spirit to an extraordinary extent will occur, as pointed out by Dr. Hooker some years ago in the Appendix to his 'Himalayan Journal.' If my informant's statement appear exaggerated, I hope the probable truth which underlies it may draw attention to the question.

"The causes just alluded to, and the comparatively short time which has elapsed since these observations were commenced, must be accepted as some justification of the meagreness of the results.

"The readings of the minimum temperature of the autumn and summer months at elevations of 9000 to 15,000 feet (Table III.) appear rarely to fall below —10° Cent., or if they do, the condition of the thermometer is generally stated by observers to be suspicious. The lowest winter reading registered is —41° C., in the case of a thermometer placed on the Col d'Argentière at a height of upwards of 12,000 feet; but as when observed the spirit had separated, we have no right to assume that it had not done so before the index attained its actual position. We have, however, four observations which seem entitled to entire confidence as far as the instrument is concerned, though one at least certainly does not represent the lowest temperature of the air. The minimum on the Becca di Nona, near Aosta, carefully deposited in a cairn at a height of 10,382 feet, has been found in perfect working order after the lapse of two years. My excellent friend M. Carrel informs me that the minimum temperature of the winter of 1860–61 and 1861–62 was respectively — 27° and — 23° C. (— 17° and — 10° Fahr.). Again, a similar instrument on the Col d'Erin, at a height of 11,408 feet, was found in perfect preservation by Mr. Whately last autumn after exposure during one winter, that of 1860–61. Its minimum reading was — 21° C. (— 6° Fahr.); but as earlier in the season I was unable to find it, though it had been deposited by myself in 1860, there is no doubt that it must have been buried in the snow during either the spring or winter, and thus its indications are probably considerably too low, since for the same period the temperature on the Becca di Nona (1000 feet lower) fell to — 27°. Lastly, a thermometer placed last year in a cairn on Scaw-Fell Pike appeared to be in good order this spring, and registered — 10° C. (+ 14° Fahr.) as the greatest winter cold.

"To the above observations it may not be amiss to add one by M. Lizat on the Pic de Nethou, the highest point of the Pyrenees (11,168 English feet). This instrument, placed at the summit, registered — 24°·2 C. in the winter of 1857. If we compare the preceding observations with the registers kept at Geneva and the Great St. Bernard, we have during the winter 1859–60 at Geneva the minimum readings of — 23° on 21st Dec. 1859, and — 11°·1 on 16th February 1860. Corresponding to these, the lowest temperatures recorded at the Great St. Bernard were — 27°·2 on 16th December 1859, and — 25°·3 on 10th March 1860. Even allowing that we are not certain that the instruments at levels higher than the Great St. Bernard were clear

TABLE I.—Observations of the Effect of the Sun's radiant Heat upon Black-Bulb Thermometers exposed during three minutes to the sun, the initial temperature being that of the air in the shade.

Observer's Name.	Place.	Height in English feet.	Date.	Hour.	Initial Temperature.	Temperature after exposure.	Difference.
Rev. T. G. Bonney	Summit of Kleiner Matterhorn	12,749	11 Aug. 1860	11.0 A.M.	−2°	21·75°	23·75°
,, ,,	Col de St. Theodule	10,899	,, ,,	1.0 P.M.	7	29·75	22·75
,, ,,	Col de la Dent Blanche	11,398	30 Aug. 1860	11.30 A.M.	3·7	28	24·3
Mr. R. B. Hayward	Lucerne	1,450?	8 Aug. 1860	11.35 A.M.	18·2	41·5	23·3
Rev. Leslie Stephen	Langenfluh, above Saas	8,300?	31 July 1860	7.0 A.M.	4	25	21
,, ,,	Summit of Mittelhorn	11,188	8 Aug. 1860	Noon.	−1	27	28
,, ,,	Summit of Alphubel	13,803	9 Aug. 1860	Noon.	−5	24	29
,, ,,	Foot of Oberaar Glacier	7,500	23 Aug. 1860	2.15 P.M.	15	35	20
J. Ball	Mont Cenis Posthouse	6,398	8 July 1860	6.50 A.M.	9·3	17·5	8·2
,,	Baths of Valdieri	4,426	14 July 1860	1.10 P.M.	18·9	39·5	20·6
,,	2000 feet above Canobbio	2,689	2 Aug. 1860	7.50 A.M.	19·3	36·7	17·5
,,	Locarno, Lago Maggiore	689	3 Aug. 1860	6.25 A.M.	16·8	27	10·2
,,	400 feet above Lenzumo	2,685	13 Aug. 1860	9.40 A.M.	16·7	37·3	20·6
,,	60 feet above Penzolo	2,532	16 Aug. 1860	9.0 A.M.	20·5	40·7	20·2
,,	,, ,,	,,	,, ,,	11.15 A.M.	23·1	44·6	21·5
,,	,, ,,	,,	18 Aug. 1860	7.30 A.M.	15·3	22·3	7·0
,,	Summit of Schleeren	8,399	25 Aug. 1860	1.10 P.M.	8·5	30·7	22·2
,,	Ratzes Bad	4,125	26 Aug. 1860	8.20 A.M.	15·8	33·2	17·4
,,	,, ,,	,,	,, ,,	11.25 A.M.	17·9	37·5	19·6
,,	Châlet of Maulknecht	7,209	27 Aug. 1860	10.15 A.M.	17·7	36·5	18·8
,,	Lower Châlets of Duron	4,500?	,, ,,	1.15 P.M.	20·6	39·5	18·9
,,	Bassano	457	21 Sept. 1860	12.50 P.M.	21·3	39·5	18·2
,,	,,	,,	,, ,,	4. 0 P.M.	21·2	34·2	13·0
,,	,,	,,	22 Sept. 1860	5.15 P.M.	21·6	26·6	5·0
,,	Eaux Bonnes, Pyrenees	2,458	25 July 1861	11.40 A.M.	24·6	47·8	23·2

J. Ball	Grotte de Rebenacq	650?	29 July 1861	Noon.	23·2	44·7	21·5
,,	Eaux Bonnes, Pyrenees	2,458	4 Aug. 1861	12.35 P.M.	19·7	41·7	22·0
,,	,, ,, ,,	,,	,, ,,	3.5 P.M.	21·4	42·6	21·2
,,	Plateau de Gourzy	5,000?	,, ,,	4.30 P.M.	20·0	37·6	17·6
,,	Eaux Bonnes	2,458	11 Aug. 1861	2.0 P.M.	25·8	46·5	20·7
,,	Brèche de Roland	9,200	16 Aug. 1861	10.45 A.M.	19·0	42·0	23·0
,,	Eaux Bonnes	2,458	27 Aug. 1861	Noon.	24·8	46·1	21·3

TABLE II.—Observations of the Temperature of the Soil at and near the surface.

Observer's Name.	Place.	Height in English feet.	Date.	Hour.	Temperature in Shade.	Temperature of Soil.	Depth.
Mr. A. T. Malkin	Col de la Seigne	8,163	26 July 1860	1.0 P.M.	7°·0	9°	1 inch.
,, ,,	,, ,,	,,	,, ,,	,,	,,	7	3 inches.
,, ,,	Les Poupets	9,500?	30 July 1860	Noon.	6	5	1 inch.
,, ,,	Col de l'Arietta	9,656	31 July 1860	10.0 A.M.	0	8	1 inch.
,, ,,	,, ,,		,, ,,	,,	,,	15	4 inches.
,, ,,	Campiglia	5,000?	,, ,,	1.0 P.M.	15·5	16	1 inch.
,, ,,	Col di Realo	?	1 Aug. 1860	7.0 A.M.	2	1	1 inch.
,, ,,	,, ,,	?	,, ,,	,,	,,	4	4 inches.
,, ,,	Col de Ponton	?	,, ,,	10.0 A.M.	9·5	5	1 inch.
,, ,,	,, ,,	?	,, ,,	,,	,,	9	4 inches.
,, ,,	Fenêtre de Cogne	?	,, ,,	11.30 A.M.	4	5	1 inch.
,, ,,	,, ,,	?	,, ,,	,,	,,	9	4 inches.
,, ,,	Redoubt above Breuil	9,000?	8 Aug. 1860	1.0 P.M.	4	11	1 inch.
J. Ball	Rocks of Trugberg	10,300?	20 Aug. 1857	1.0 P.M.	7·2	28·4	1 inch.
(all in dry soil).	,, ,,	,,	,, ,,	,,	,,	23·7	5 inches.
,,	,, ,, (shade, soil not dry)	,,	,, ,,	,,	,,	5·5	2 inches.
,,	Plain of Mont Cenis	6,300	8 July 1860	Noon.	19·6	32·8	1 inch.
,,	,, ,,	,,	,, ,,	,,	,,	26·4	4 inches.
,,	Monzoni, Fassa	about 7,500	28 Aug. 1860	12.20 P.M.	17·2	31·5	1 inch.
,,	200 feet below Port de Venasque	8,425	5 Sept. 1861	12.20 P.M.	17	42·2	surface.
,,	,, ,, ,, ,,	,,	,, ,,	,,	,,	37·0	1½ inch.

TABLE III.—Observations made wit

Station.	Height in English feet.	Spirit or Mercury.	No. of instrument.	Position.	By whom placed.	Date of depos
Mont Blanc	15,784	S	...	Pennine Alps	Prof. Tyndall.	1859. Aug. 21.
Monte Rosa (Höchste Sp.)	15,217	S	316	,, ,,	Col. Robertson.	1860. July 16.
,, ,, (Nordend)...	15,132	S	...	,, ,,	Sir T. F. Buxton,	1861. Aug.
Finsteraarhorn	14,046	S	313 ?	Bernese ,,	Rev. L. Stephen.	1861. Aug. 5.
,, ...	,,	S	318 ?	,, ,,	F. F. Tuckett.	1860. July 27.
Corridor (Mt. Blanc)	14,000 ?	S	...	Pennine ,,	Prof. Tyndall.	1859. Aug 21.
Castor	13,879	S	375	,, ,,	W. Mathews, Jun.	1861. Aug. 23.
Grand Paradis	13,300	S	367	Graian ,,	F. F. Tuckett.	1861. July 3.
Grivola	13,005	M	...	,, ,,	,, ,,	1862. June 27.
Gd. Pelvoux (Signal)	12,919	M	...	Dauphiné.	,, ,,	1862. July 10.
Gd. Plateau (Mt. Blanc)	12,900 ?	S	...	Pennine Alps.	Prof. Tyndall.	1859. Aug. 21.
Col d'Argentière	12,600 ?	S	314	,, ,,	F. F. Tuckett.	1860. Aug. 2.
Monte Viso	12,586	S	301	Collian ,,	W. Mathews, Jun.	1861. Aug. 30.
,, ,, ...	,,	M	...	,, ,,	F. F. Tuckett.	1862. July 4.
Aiguille du Goûté.........	12,530	S	372	Pennine ,,	,, ,,	1861. July 17.
La Sassière	12,400	S	302	Graian ,,	W. Mathews, Jun.	1860. Aug. 5.
Oberaarhorn...............	11,923	S	...	Bernese ,,	Rev. L. Stephen.	1860. Aug.
Mont Emilius	11,788	M	...	Graian ,,	W. Mathews, Jun.	1862. Aug. 1
Trift Joch	11,601	S	333	Pennine ,,	Rev. T. G. Bonney.	1860. Sept.
Mont Gelé	11,539	S	384	,, ,,	F. W. Jacomb.	1861. Aug. 11.
Col d'Erin..................	11,408	S	318	,, ,,	F. F. Tuckett.	1860. July 18.
Marmolata	11,300 ?	S	...	S. Tyrol.	J. Ball.	1860. Sept. 1.
Mittelhorn	11,190	S	...	Pennine Alps.	Rev. L. Stephen.	1860.
Grauhaupt..................	11,030	S	335	,, ,,	A. T. Malkin.	1860. Aug. 23.
Becca di Nona	10,382	S	306	Graian ,,	,, ,,	1860. Aug.
Col de Chermontane	10,349 ?	S	...	Pennine ,,	Sir T. F. Buxton.	1861. Aug.
Aeggischhorn Peak	9,649	S	312	Bernese ,,	F. F. Tuckett.	1860. July 24.
Faulberg	9,150 ?	S	315	,, ,,	,, ,,	1860. July 26.
Glacier des Bossons	?	S	...	Pennine ,,	Prof. Tyndall.	1859. Aug. 21.
Faulhorn	8,804	S	...	Bernese ,,	E. Anderson.	1860. Sept.
Aeggischhorn Inn.........	7,150	S	310	,, ,,	F. F. Tuckett.	1860. July 24.
Scaw-Fell Pike	3,160	S	339 ?	England.	R. B. Hayward.	1861. Aug.

of winter snow, there is at least reason to suspect that the proportionate fall of the thermometer with increase of height is much less considerable in winter than at other seasons."—F. F. TUCKETT.

2. The objections to attempting a measure of the radiant heat of the sun by exposing black-bulb thermometers, are obvious and well known; nevertheless it was thought that by using instruments as nearly as possible identical in construction, exposed in the same manner, and rejecting all observations in which the result could be affected by wind, results comparable *inter se* might be obtained. It is believed that if the first condition could be secured this inference would be found correct, but in point of fact it is a matter of extreme difficulty to obtain the requisite identity of construc-

lpine Minimum Thermometers.

Lowest Temp. recorded.	By whom observed.	Date of observation.	Remarks.
C.			
−14°·8	W. Mathews, Jun.	1859. Aug. 29.	1861, July 19, F. F. Tuckett, "Spirit separated." Sept., F. W. Jacomb, ditto.
−17°	T. Blandford.	1860. Aug. 30.	1861, Aug. 10, Dr. Kolbs, "Spirit disappeared, no flow visible; index on bottom of bulb."
No obs.			
−25°	H. Lawrence.	1861. Aug. 25.	Touched, and possibly disturbed by guide.
−10°	T. Blandford.	1861. Aug. 7.	Reset on 5th by Rev. L. Stephen. Aug. 23, 1861, H. Lawrence, "No index visible."
No obs.			
"			
"			
"			
"			
−7°	W. Mathews, Jun.	1859. Aug. 29.	
−35°?	S. Winkworth.	1861. June 22.	"Minimum −41°. Spirit separated from +21°·5 to +32°·5." Result doubtful.
No obs.	... ...	... ...	1862, July 4, F. F. Tuckett, "Cairn partly buried in snow; could not find therm."
"	... ...	... ...	1862, July 4, F. F. Tuckett, "Securely deposited in upper part of cairn."
"	... ...	... ...	1861, Sept., F. W. Jacomb, "Not to be found; probably stolen."
"			
"	J. K. Stone.	1860. Aug.	"Spirit separated."
"			
−9°	Rev. C. H. Pilkington.	1861. Aug. 17	"Spirit separated from 10°·5 to 11°·5, and from 36°·5 to 39°." 1860, Sept. 14, R. B. Shaw, −8°·5.
No obs.			
−21°	A. P. Whately.	1861. Aug. 19.	"In good order, and agreed with Mr. W.'s thermometer."—1861, June 25, F. F. Tuckett, "Not to be found; probably covered with snow."
No obs.			
"			
−1°·7	F. J. A. Hort.	1860. Sept. 5.	"Stood 0°·5 C. lower than a mercurial thermometer by Mr. Casella."
−27°, 1861	M. Carrel	1861. June 27.	1860, Aug. 8, G. H. Strutt, −7°. 1861, Aug. 9, F. W. Jacomb, −7°.
−23°, 1862	" "	1862. June.	
No. obs.			
−9°	T. Webster.	1860. Sept. 9.	1861, July 4, W. G. Fry, "Could not find thermometer, and believed it had been broken."
−12°·5	T. Blandford.	1861. Aug. 6.	1860, Aug. 18, Rev. L. Stephen, −3°.
...	W. Mathews, Jun.	1859. Aug. 29.	"Index close to bulb, and evidently not properly set when deposited by Balmat."
No obs.			
−2°	F. J. A. Hort.	1860. Sept. 27.	1861, July 5, 31° (?) De la Fontaine.
−10°·5	Messrs. Green and Smallpiece.	1862. May 28. 1862. Sept. 24.	In good order.

tion. Among the instruments provided for the purpose by Mr. Casella, the writer has found that a slight difference in the size of the bulb has a very marked difference in the indications of the instrument, amounting in some cases to 2°·5 C.

It was also found that the interval of three minutes allowed for the exposure of the black-bulb thermometer to the sun was too great. At considerable heights the air does not often remain perfectly calm, nor the sky completely clear of passing films of cloud, for many minutes together. It is necessary to allow an interval long enough to make an error of, say, one second in the moment of reading the instrument not very sensible in the observation; but one minute is certainly preferable to three; and after experience had disclosed the mistake, the writer always recorded three readings, corresponding to one, two, and three minutes of exposure.

The season of 1860 was unusually inclement, and the sky rarely in favourable condition, so that in the course of about eight weeks the writer obtained but thirty-nine observations, of which the large majority were taken under unfavourable circumstances, and must therefore be rejected.

In 1861 fifteen observations were made in the Western Pyrenees under more favourable conditions.

In addition to the above, several observations made in 1860 by the Rev. T. G. Bonney, Mr. R. B. Hayward, Rev. F. J. A. Hort, Mr. A. T. Malkin, and the Rev. Leslie Stephen have been communicated by those gentlemen to the writer. Excluding those fairly open to suspicion, the results are registered in the annexed Table (I.). An accurate comparison of these results would involve as one element the altitude of the sun at the moment of each observation, but the sources of error are too many and considerable to make this worth the requisite trouble. All that can fairly be inferred from the Table is that the sun's rays produce a greater effect on the black-bulb thermometer at higher than at lower levels, the difference, though quite perceptible, being not considerable in amount. It is true that the highest reading out of twenty-four observations by the writer recorded in the Table was at Eaux Bonnes, only 2458 feet above the sea; but without considering the probability that that reading was exaggerated by the radiation of heated bodies (walls, &c.) near the thermometer, it will be observed that it was made at 20 min. before noon on July 25, and does not therefore indicate as great an effect of solar radiation as the observations made on the Schleeren (8399 ft.) at 1.10 P.M. on August 25, or on the Brèche de Roland (9200 ft.) at one hour and a quarter before noon on August 16.

3. As might, perhaps, have been anticipated, the attempt to trace the propagation of disturbances in temperature by means of a network of observations covering a considerable tract of mountain country resulted in complete failure. Even if the observers had been more numerous and more diligent than they were, the disturbing effects of local causes are far more serious than was apprehended. The effects of vicinity of the soil in raising the indications of the thermometer by day and lowering them by night, are not yet as fully measured or appreciated as they ought to be, and it is questionable whether the observations made at fixed observatories are as nearly comparable as they are commonly supposed to be. Among other authorities on this point, a recent memoir by Mr. Charles Martins might be referred to as showing how important is the effect of slight differences of level on the nocturnal indications of the thermometer.

The welcome intelligence that the Swiss men of science are about to establish fixed stations for systematic observations of the thermometer and other meteorological instruments throughout the territory of the Confederation makes the disappointment on this head less important, as it is probable that, with requisite skill and caution in observing and reducing the results, the plan now believed to be definitively adopted will much enlarge our knowledge of Alpine meteorology.

4. Observations on the temperature of the soil at and near to the surface in mountain countries are of considerable interest from their bearing on the distribution of animals and plants. It is not too much to say that if such observations had been available, M. Alphonse DeCandolle would have been led to modify several of the conclusions stated in his standard work on

Geographical Botany, respecting the conditions of life to which high alpine plants are subjected.

Regarded only as an object of physical inquiry, it is clear that the only observations which can be considered in any degree comparable are those made in *dry soil*, and this condition is so seldom fulfilled, that comparatively few observations have been obtained. Some made by the writer, and several others communicated by Mr. A. T. Malkin, but apparently not made in quite dry soil, agree in showing that in the higher regions of the Alps, approaching to and above what is commonly called the limit of perpetual snow, the plants and animals that dwell on the surface of the soil must, during the short period of their active vitality, receive an amount of heat much larger than has commonly been supposed. The annexed Table (II.), although too limited to furnish general results, may be worth preserving as evidence upon this point.

Report of the Committee for Dredging on the North and East Coasts of Scotland. *By* J. GWYN JEFFREYS, *F.R.S.*

THE Marine Invertebrata enumerated in the following list were found by Mr. Robert Dawson on that part of the coast of Aberdeenshire which extends from the mouth of the Ythan to the mouth of the Ugie. The distance in a straight line is about 15 miles. The whole of this coast, with the exception of the sands of Forvie and the little bays of Peterhead and Cruden, consists of precipitous granite and gneiss rocks.

The sea-bed appears to slope gently and regularly from the shore for 10 or 12 miles, the only exception to this uniformity being a ravine (or *Hole* as it is called by the fishermen) opposite to Slains Castle. This ravine commences about half a mile from the shore, and stretches out at right angles to the land, the depth varying from 25 fathoms to 35 fathoms.

The Laminarian zone, which, except about Peterhead, is very narrow, is succeeded by a belt of pure white sand, extending in breadth to the 30-fathom line from 3 to 4 miles from the shore. This sand has in general been very unproductive, but in the ravine just mentioned many of the rarest species have been got.

Dredging may be said to have begun at 30 fathoms, and extended over the Coralline zone till it attains a depth of 90 fathoms. On one occasion the dredge was used in 60 fathoms, at a distance of 15 or 16 miles from shore. Two of the species enumerated in the list were brought up by a fisherman's line 30 miles from land (viz. *Trophon scalariformis* and *Pinna pectinata*).

The following abstract shows the number of Mollusca identified:—

Gasteropoda Prosobranchiata	110
—— Opisthobranchiata	11
—— Nudibranchiata	8
Pteropoda	1
Conchifera Lamellibranchiata	92
—— Brachiopoda	1
	223

Of this number the following are *Arctic* and probably fossil, viz. *Trophon scalariformis*, *T. Gunneri*, *Astyris Holböllii*, *Scalaria Eschrichti*, *Natica clausa* and *helicoides*, *Margarita cinerea*, *Skenea? costulata*, *Adeorbis subcarinata*, *Lepeta cæca*, *Astarte arctica* and *elliptica*, *Tellina proxima*, *Scrobicularia* *piperata*, *Mya truncata*, *Saxicava rugosa*, and *Hypothyris psittacea*, besides the *Pecten islandicus*, which is not unfrequently dredged.

Some of these fossil shells have been found in almost every haul of the dredge, as *Astarte elliptica*, *Tellina proxima*, *Pecten islandicus*, and *Saxicava rugosa*.

All the others, with the exception of *Scrobicularia piperata*, have been found in three different spots, viz. the Hole, before mentioned, opposite the mouth of the Ythan, 6 miles from land, in 40 fathoms, and opposite the mouth of the Ugie, 6 miles from land, in 35 fathoms,—that is, exactly at each extremity, and in the middle of the space which has been dredged over by Mr. Dawson.

But although the fossil species found appear to be principally confined to the three spots indicated, yet the presence of some of them wherever the dredge has been used tends to prove that a tertiary bed extends along the whole coast and to a great distance seaward, some of these fossils having been brought up 30 miles from land by the fishermen's lines. Of the 17 apparently fossil species enumerated, 10 have been found in a decidedly fossil state in the *drift clay* in different parts of the county *. These are—

Trophon scalariformis......	at Belhelvie, near the sea.
Natica clausa..................	at King Edward, several miles from sea,
—— helicoides...............	at King Edward, ditto.
Astarte arctica	various places.
—— elliptica	ditto.
Tellina proxima	ditto.
Scrobicularia piperata	raised beach at Ythan Mouth.
Mya truncata	King Edward.
Saxicava rugosa	Belhelvie, &c.
Pecten islandicus	ditto.

Of species usually accounted rare, the following are rather common in this district, viz.:—

Lepton nitidum.
—— convexum.
Lima subauriculata.
Skenea divisa.
—— costulata.
Aclis ascaris.
—— supranitida.
Eulimella Scillæ.
—— acicula.

There are a few species enumerated by Dr. Gordon in his 'List of the Mollusca of the Moray Firth' which do not appear to have been found by Mr. Dawson; the late Prof. Macgillivray also, in his 'Mollusca of Aberdeenshire,' records some which Mr. Dawson has not met with.

Note on BOLOCERA EQUES.

Dredged off Peterhead in 35 fathoms on June 20, 1862, and still alive.

Base.—As described by Mr. Gosse in his 'Actinologia Britannica.'

Column.—Upper half covered with longitudinal rows of close-set warts, in ordinary circumstances not minute, but very variable in size at the pleasure of the animal.

Disk.—As described in 'Act. Brit.'

Tentacles.—Arranged as described in 'Act. Brit.,' but several of them having double points, and thus causing their number to appear to be 150 or upwards. They are extremely variable in shape, being sometimes contracted to a mere thread, and at other times distended till they are almost globular.

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* Mr. Jamieson of Ellon supplied Mr. Dawson with this list of fossils. He has specimens of many other Arctic shells from the same beds, but these are either still alive in the district, or have not been found with the dredge.

The apex appears to be more truncate than that described and figured by Mr. Gosse.

Mouth.—As described in 'Act. Brit.'

Colour.

Column.—Straw-colour; striæ nearly white; warts, when fully expanded, white, with a pellucid spot in the centre.

Disk.—General colour similar to that of the column, radiated with white striæ, with conspicuous radiating deep-red bands arising from a point within each inner tentacle, and passing in pairs round the tentacles, exactly as in *Tealia crassicornis.*

Tentacles.—Pellucid white; a broad magenta ring near the apex, gradually shading into pellucid white above the middle, and succeeded by an opake white band.

Size.

Height of column, 2 inches.

Length of tentacles, when fully expanded, 5 inches.

This specimen is still (Sept. 17, 1862) in full health and beauty; it has lost, however, a little of the brilliancy of the magenta or purplish colour on the tentacles. On some occasions it has slightly shifted its base on the stone to which it adheres, and after a few days moved back to its former site.

In presenting this Report, Mr. Jeffreys observed that its most peculiar and interesting feature was the discovery of so many Arctic species of shells in a fossil state, mixed with recent shells of other species. He accounted for this assemblage of fossil and recent shells in the same spot by supposing that towards the close of the glacial epoch the sea-bed containing these arctic shells was gradually upheaved and became dry land, so as to exterminate the breed, and that subsequently the bed was submerged and inhabited by other species, which had either migrated from the south, or were diffused in course of time over the present area of the German Ocean. Such a state of things would imply very long periods of elevation and subsidence.

Report of the Committee, consisting of the Rev. W. VERNON HARCOURT, Right Hon. JOSEPH NAPIER, Mr. TITE, *M.P.,* Professor CHRISTISON, Mr. J. HEYWOOD, Mr. J. F. BATEMAN, Mr. T. WEBSTER, *on Technical and Scientific Evidence in Courts of Law.*

WRITERS on legal evidence have frequently animadverted on the testimony of professional witnesses in a Court of Justice as being contradictory and unreliable, in a degree which materially diminishes its value; nor is it denied among the candid members of more than one profession that greater contrarieties of opinion on technical and scientific subjects appear in the *witness box* than can be satisfactorily accounted for, or than would be likely to arise anywhere else.

The effect of such contradictions is not only to leave doubts on many important issues which art and science might well have decided, but to lower the authority and credit of all that class of evidence to such a point, that it has even been proposed very recently to dispense with it altogether in some cases which seem most to require the light that it might afford.

The principal cause which has thus shaken the credit of professional testimony is to be found, not in those differences of judgment which we might reasonably expect when we view it as a species of evidence embracing *inferences* as well as *facts*, but rather in the anomalous practice of engaging technical and scientific witnesses *ex parte*, to prove a case on either side.

In vindication of such a practice, it may be said that there is no other method by which the truth can be so well elicited, and justice therefore so well administered. As the arguments of counsel *ex parte* for their respective clients bring out before the judge and jury all that can be alleged on either side in point of reasoning, so may the facts adduced in the same manner by professional witnesses be considered as giving a more complete view of the *data* for determining a question than if they were sought by an indifferent inquirer.

This statement might be accepted as satisfactory, if professional witnesses were engaged to investigate *facts* only; but they are engaged also to deliver *opinions*; and opinion, even in conscientious minds, is prone to follow the side which it is employed to support; whilst less scrupulous witnesses are induced by the position in which they are placed to utter opinions different from those which they have been known to deliver on the same points under other circumstances.

The evil of such a state of things is undeniably great, not only as regards the credit of honourable professions, but the public administration of the law; for questions of importance are thus tried under the double disadvantage of testimony which can be only partially trusted, and juries who are incompetent to sift it, because relating to subjects with which they are little acquainted. Nor are these questions of rare occurrence; technical evidence has of late been greatly extended, in proportion to the rapid progress of the arts; and it must be remembered that it comprehends *trades* as well as professions, including all cases in which experts are called in to speak to facts or inferences of which persons inexperienced in the trade or profession are incapable of judging. So numerous and important have these cases become, that the evidence which affects them cannot but be considered as having gained such a place in our jurisprudence as to demand a careful revision of its very serious defects.

For some years past, various schemes of alteration in the existing practice of the courts have been suggested. In a lecture delivered by Dr. Christison before the Edinburgh College of Physicians in 1851, and in papers read by Dr. Angus Smith in 1857 and subsequent years before various societies, the whole subject has been ably discussed; the attention of several legal and judicial authorities has also been drawn to it by Mr. Harcourt; and the Committee consider themselves as having gained sufficient information to perform the duty entrusted to them by the Association of "suggesting improvements in the present practice respecting scientific evidence as taken in Courts of Law."

Any attempt to supersede the existing system, as respects the liberty of each party in a suit to obtain evidence for its own case on technical questions, whether of fact or opinion, the Committee would regard as impracticable. But they are of opinion that such *checks* on *ex parte* evidence might be introduced with advantage as would counteract some of its injurious tendencies, and would lead, in a conflict of opinions, to a better judgment on the merits of the case.

In days less scientific than the present there were questions of great importance in a maritime country, the just decision of which required more technical knowledge than any ordinary jury could be supposed to possess.

It has long been allowed therefore to transfer cases which would have been blindly determined by persons possessing no *nautical* skill, from the ordinary tribunals to a judge assisted by a certain number of Masters of the Trinity House, before whom the evidence is given.

The result of all the inquiries which the Committee have been enabled to make is, that there will be found no method of correcting the present practice in the trial of intricate scientific questions, so little open to exception as one that should be founded on the principle thus already adopted in questions of navigation.

There is reason to believe that opinions in evidence stated before a Court capable of appreciating them would be given with a greater measure of care and a more prudent reserve, and that a judge assisted by assessors who (being themselves experts) fully understood the technical value of the evidence, would deliver a judgment more founded in reason and accordant with justice than can ever be obtained from the present tribunals.

The Committee would therefore propose that, by a legislative act, judges should be empowered, on application from a suitor, in causes of a technical character, to convene skilled assessors, the number of whom should not exceed three, and who should give their opinions truly on the statements of the witnesses, in such manner as they shall be required by the judge, previous to his adjudication of the cause.

A Court constituted as is here proposed might see a necessity in some cases for *independent* evidence of the facts on which either party relied. The allowing the judge to call in witnesses independent of the parties in such cases, as is done on various occasions by Courts of Chancery and by Parliamentary Committees, is a measure which has been suggested by a high judicial authority, and would, in the opinion of the Committee, be a valuable supplement to the preceding provision.

In recommending these changes, the Committee have had in view the evidence given in *civil* causes: in *criminal* cases the opinions of witnesses are ar less affected by partisan feelings. There may be a few instances, however, in which it might serve the interests of public justice that the judge should have power to direct an issue to be tried by a Court constituted on the principles here proposed. But the defect of the scientific evidence in criminal causes chiefly consists in want of competence on the part of the witnesses: questions, for instance, of secret poisoning sometimes hang on the judgment of a practitioner or analyst of insufficient experience. The remedy for this deficiency is indeed understood to be virtually in the hands of the magistracy, since the Government authorities never refuse to select proper persons for the investigation of cases in which the Crown is concerned; but the Committee are of opinion that it would be an important improvement on the present practice, if the magistrates were advised that application should be made by them for the appointment of such competent persons by the Crown in every case requiring accurate scientific investigation.

If the recommendations contained in this Report should be approved by the Association, the Committee would advise that they should be laid before the Secretary of State for the Home Department, with an application for his concurrence in carrying them into effect, and that the Parliamentary Committee of the Association should be requested to support the application, and to promote any Bill in Parliament which may be founded on the foregoing principles.

An Account of Meteorological and Physical Observations in Eight Balloon Ascents, made, under the Auspices of the Committee of the British Association for the Advancement of Science at Manchester, by JAMES GLAISHER, *F.R.S., at the request of the Committee, consisting of Colonel Sykes, Professor Airy, Lord Wrottesley, Sir D. Brewster, Sir J. Herschel, Dr. Lloyd, Admiral FitzRoy, Dr. Lee, Dr. Robinson, Mr. Gassiot, Mr. Glaisher, Dr. Tyndall, Mr. Fairbairn, and Dr. W. A. Miller.*

THE objects to which the Committee resolved to devote their principal attention were the determination of the temperature and hygrometric condition of the air at different elevations above the earth's surface. In addition to which, several other secondary objects were to be carried out if possible, as follows:—

§ 1. OBJECTS OF THE EXPERIMENTS.

The *primary* objects were—

The determination of the temperature of the air, and its hygrometrical states, at different elevations, as high as possible.

The *secondary* objects were—

To determine the temperature of the dew-point by Daniell's dew-point hygrometer, by Regnault's condensing hygrometer, and by dry- and wet-bulb thermometers as ordinarily used, as well as when under the influence of the aspirator; so that considerable volumes of air were made to pass over both their bulbs, at different elevations, as high as possible, but particularly up to those heights where man may be resident, or where troops may be located, as in the high lands and plains in India, with the view of ascertaining what confidence may be placed in the use of the dry- and wet-bulb thermometers at those elevations, by comparison with the results as found from them, and with those found directly by Daniell's and Regnault's hygrometers, and to compare the results as found from the two hygrometers together.

To compare the readings of an aneroid barometer with those of a mercurial barometer up to 5 miles.

To determine the electrical state of the air.

To determine the oxygenic condition of the atmosphere by means of ozone papers.

To determine the time of vibration of a magnet on the earth, and at different distances from it.

To collect air at different elevations.

To note the height and kind of clouds, their density and thickness.

To determine the rate and direction of different currents in the atmosphere, if possible.

To make observations on sound.

To note atmospherical phenomena in general, and to make general observations.

Instruments and Apparatus.

The instruments used were mercurial and aneroid barometers; dry- and wet-bulb thermometers; Daniell's dew-point hygrometer; Regnault's condensing hygrometer; maximum and minimum thermometers; a magnet for horizontal vibration; hermetically sealed glass tubes from which air had been exhausted; ozone papers; and an electrometer lent by Prof. W. Thomson of Glasgow.

Barometers.—The mercurial barometer employed in all the ascents was a Gay-Lussac's siphon barometer by Mr. P. Adie, and is one of those used by Mr. Welsh in the year 1852 in his experiments. The inner diameter of its tube is 0·25 inch. The graduations were made on a brass scale, from its middle point upwards and downwards; each division was about 0·05 inch in length, representing twice that value, so that an observation of either the lower or upper surface of the mercury would give the approximate length of the column of mercury.

The readings of the upper end were alone taken, and the corrections applicable to this end have been applied to all observations.

The barometer was furnished with its own thermometer, whose bulb was immersed in a tube of mercury of the same diameter as that of the barometer.

This instrument sometimes read more than 20° in excess of that of the sensitive air-thermometer.

The aneroid barometers were made by Messrs. Negretti and Zambra; one was graduated to 13 inches, and the other to 5 inches—the latter instrument having been used in the ascents on August 18 and September 5, and the former on July 17. In consequence of a difference of reading between the aneroid and mercurial barometers on July 17 (and as both instruments were broken, it was impossible to say which was in error), and as the correctness of the siphon barometer at low readings is dependent upon the evenness of the tube, another barometer was used in addition on September 5, made by and at the suggestion of Messrs. Negretti and Zambra, as follows:—

A tube 6 feet in length was filled with mercury and boiled throughout its whole length; a glass cistern was blown on the bottom of the tube, and bent upwards in the form of a siphon; a stopcock was placed between the tube and cistern, and whilst the mercury filled the entire tube, a mark was made on the cistern, at the level of the mercury in it, for zero; the stopcock was then gradually opened, and the mercury allowed to descend one or more inches. The rise which consequently took place in the cistern was carefully marked on the same side as "0" (zero); the stopcock was again opened and the same operation was repeated until 30 inches of mercury had left the upper part of the tube, and the successive levels of the mercury in the cistern had been accurately marked.

In finally making the barometer, the upper portion only of the tube was used; the cistern which had been at the end of the lower portion was removed and joined on the upper; and in graduating the scale of the barometer, the rise which took place in the cistern at every inch was deducted, and the scale reduced in its entire length, by the exact amount of the rise of the mercury in the cistern. This instrument was therefore probably as accurate at low readings as at high.

Dry- and Wet-Bulb Thermometers.—Two pairs of dry- and wet-bulb thermometers were employed; one pair as ordinarily used, their bulbs being protected from the direct rays of the sun by a double highly polished silver shade, in the form of a frustum of a cone, open at top and bottom. A cistern was fixed near to them, from which water was conveyed to the wet-bulb thermometer.

The bulbs of the second pair of dry- and wet-bulb thermometers were enclosed in two silver tubes placed side by side, and connected together by a cross tube joining their upper ends, and over both were placed double shades as in the other pair of thermometers. In the left-hand tube was placed the dry-bulb, and in the right-hand tube the wet-bulb thermometer. Towards the lower end of the left-hand tube there was an opening; by means of the aspirator a current of air was drawn in at this aperture, then passed the dry-bulb in its upward passage into the small horizontal tube, and from thence into the right-hand tube, passing downwards over the wet-bulb, and away by a flexible tube into the aspirator. These instruments were made by Messrs. Negretti and Zambra.

Regnault's Condensing Hygrometer.—This instrument was made with two thermometers, as described by Regnault in the 'Annuaire Météorologique de la France' for 1849, page 221, excepting that it was furnished with silver-gilt cups. The scale was of ivory, and the two thermometers were fixed in their cups by means of cork, for ready packing up. The instrument was made by Messrs. Negretti and Zambra.

Daniell's Hygrometer was of the usual construction, by Messrs. Negretti and Zambra.

Exhausted Tubes for collecting Air.—These tubes were partly constructed by Messrs. Negretti and Zambra, and partly by Mr. Casella.

The thermometers employed in the observations were exceedingly sensitive; the bulbs were long and cylindrical, being about $\frac{3}{4}$ths of an inch in length, and $\frac{1}{12}$th of an inch in diameter. The graduations, extended to minus 40°, were all on ivory scales. These thermometers, on being removed from a room heated 20° above that of an adjoining apartment, acquired the temperature within half a degree in about 10 or 12 seconds; but in passing from a heated apartment to one of a lower temperature, it took more than double the time to approximate to within half a degree of the latter. They were so sensitive that scarcely any correction is required to be applied to them on account of sluggishness; and this was found to be the case by the very near agreement in the temperatures at the same height in the ascending and descending curves, in those cases where there was reason to believe that there had been no change of temperature at the same height, within the interval between the two series of observations.

§ 2. OBSERVING ARRANGEMENTS.

One end of the car was occupied by Mr. Coxwell; near the other, in front of myself, was placed a board or table, the extremities of which rested on the sides of the car; upon this board were placed suitable framework to carry the several thermometers, hygrometers, magnet, aneroid barometer, &c.; a perforation through it admitted the lower branch of the mercurial barometer to descend below, leaving the upper branch at a convenient height for observing. A watch was set to Greenwich time, and placed directly opposite to myself. The central space of the table was occupied by my note-book. The aspirator was fixed underneath the centre of the board, so as to be conveniently workable by either my feet or hands. Holes were cut in the board to admit the passage of the flexible tubes, one of which passed to Regnault's hygrometer, and the other to the place of the dry- and wet-bulb thermometers previously referred to, both the tubes being furnished with stopcocks.

Circumstances of the Ascents, and General Observations.

The ascents were all made by Mr. Coxwell's large balloon,—three from Wolverhampton, four from the Crystal Palace, Sydenham, and one from

Mill Hill, near Hendon, where the balloon had fallen the evening previous, and had been anchored during the night.

Ascent from Wolverhampton, July 17.—The balloon was inflated at the Stafford Road Gas-works, Wolverhampton, with carburetted gas, most carefully prepared by the Engineer, Mr. Thomas Proud, and frequently kept a long time for our use, the Directors of the Gas Company having most liberally, to their great inconvenience, placed a gasometer at our disposal for as long a time as we needed it. To the Directors of the Company and to Mr. Proud our best thanks are due; for on all occasions they showed the utmost anxiety to contribute to the success of the experiments, in which Mr. Joseph Walker, Mr. Joseph Cooper, and Mr. Proud took great interest.

The weather previously had been bad for a long time, and the ascent had been delayed some days in consequence; the wind was still blowing strongly from the West; and considerable difficulty was experienced in the preliminary arrangements, and no instrument was placed in its position before starting. The ascent took place at $9^h\ 43^m$ A.M.; at once the balloon was quiescent. A height of 3800 feet was reached before an observation could be taken; at 4000 feet clouds were entered, which were left at 8000 feet. The temperature of the air fell to 33°, and a height exceeding 10,000 feet had been passed before all the instruments were in working order. The sky was then noticed to be of a deep-blue colour, without a cloud of any kind upon its surface.

At starting, the temperature of the air was 59°, and dew-point 55°; at 4000 feet it was 45°, dew-point 33°, and descended to 26° at 10,000 feet, dew-point 19°, and then there was no variation of temperature between this height and 13,000 feet. During the time of passing through this space, both Mr. Coxwell and myself put on additional clothing, feeling certain that we should experience a temperature below zero before we reached 5 miles high; but to my surprise, at the height of 15,500 feet, the temperature, as shown by all the sensitive instruments, was 31°, dew-point 25°; and at each successive reading, up to 19,500 feet, the temperature increased, and was here 42°, dew-point 24°. We had both thrown off all extra clothing. Within two minutes after this time, when we had fallen somewhat, the temperature again began to decrease, with extraordinary rapidity, and was 16°, or 27° less than it was 26 minutes before: at this time a height of 5 miles had been reached, at about 11 A.M.

When the balloon had attained a height of 4 miles, I wished to descend for one or two miles and then to re-ascend; but Mr. Coxwell, who had been watching its progress with reference to the clouds below, felt certain that we were too near the Wash; prudence therefore caused us to abandon the attempt.

Our descent began a little after 11 A.M., Mr. Coxwell experiencing considerable uneasiness at our too close vicinity to the Wash; we came down quickly, passing from a height of 16,300 feet to one of 12,400 feet between $11^h\ 38^m$ and $11^h\ 39^m$; dipping into a dense cloud at this elevation, which proved to be no less than 8000 feet in thickness, and whilst passing through this the balloon was invisible from the car. Mr. Coxwell had reserved a large amount of ballast, which he discharged as quickly as possible to check the rapidity of the descent; but notwithstanding all his exertions, as we collected weight by the condensation of that immense amount of vapour through which we were passing, the descent was necessarily very rapid, and we came to the earth with a very considerable shock, which broke nearly all the instruments. All the sand was discharged when we were at a considerable elevation; the amount we had at our disposal at the height of 5 miles was

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fully 500 lbs.; this seemed to be more than ample, and, when compared with that retained by Gay-Lussac, viz. 33 lbs., and by Rush and Green, when the barometer reading was 11 inches, viz. 70 lbs., seemed indeed to be more than we could possibly need, yet it proved to be insufficient.

The descent took place at Langham, near Oakham in Rutlandshire, in a meadow near the residence of Mr. E. G. Baker, from whom we received the utmost attention.

Ascent from the Crystal Palace, July 30.—A table was fixed to the side of the car, partly within and partly without. The instruments were placed on a framework, fixed to the part of the table outside, so as to be beyond the influence of the occupants of the car; my note-book, watch, and aneroid barometer rested on the inner part of the table. The air was in gentle motion from the south-west, enabling the instruments to be made ready for observation before starting, and at 4^{h} 40^{m} P.M. the balloon left the earth.

The temperature declined instantly. Observations were taken every minute or half-minute from the time of ascent, to as near as possible the time of descent.

The readings of one barometer were kindly made by Mr. W. F. Ingelow, and he also assisted me in observing the first appearance of dew on the hygrometer.

A height of 7000 feet was reached at about 6 o'clock, and the descent began about a quarter past 6; it was rather rapid, but quite under control, and we reached the earth at the village of Singlewell, near Gravesend, at 6^{h} 30^{m}.

Ascent from Wolverhampton, August 18.—The weather on this day was favourable; there was but little wind, and that blowing from the N.E. By noon the balloon was nearly inflated, and as it merely swayed in a light wind, all the instruments were fixed before starting, and at 1^{h} 2^{m} 38^{s} P.M. Mr. Coxwell pulled the spring-catch; for a moment the balloon remained motionless, and then rose steadily almost perpendicularly: this ascent was all that could be desired. In about 10 minutes we passed through a fine cumulus cloud, and then emerged into a clear space with a beautiful blue sky dotted over with cirrus clouds above. When at the height of nearly 12,000 feet, with the temperature of 38°, or 30° less than on the ground, and dew-point 26°, Mr. Coxwell discharged gas, and we descended to a little above 3000 feet at 1^{h} 48^{m}; a very gradual ascent then took place till 2^{h} 30^{m}, when a height of about 24,000 feet was obtained; and here a consultation took place as to the prudence of discharging more ballast or retaining it, so as to ensure a safe descent; ultimately it was determined not to go higher, as some clouds, whose thickness we could not tell, had to be passed through. The descent began soon after, and we reached the earth a little after 3 o'clock at Solihull, about 7 miles from Birmingham.

Ascent from the Crystal Palace, August 20.—The air was almost calm, the instruments were all fixed before starting, and the balloon left the Crystal Palace at 6^{h} 25^{m} P.M., the temperature at the time being 66°, dew-point 54°. By 6^{h} 35^{m} we were half a mile high, the temperature being 56°. At 6^{h} 37^{m} the height of three-quarters of a mile was attained, and the air was so tranquil that we were still over the Palace. At 6^{h} 43^{m}, when at the height of nearly a mile, a thick mist or thin cloud was entered, the earth being just visible. The temperature at this time was 50°, dew-point 46°; this elevation and temperature were maintained for about five minutes, and we then descended 200 or 300 feet. Kennington Oval was in sight. At 7^{h} 9^{m} St. Mark's Church, Kennington, was exactly underneath us. We were now about a mile in height, with a temperature of 48°, and dew-point 46°; the hum of London was heard, and there was scarcely a breath of air stirring.

A descent was gradually made to 1200 feet by $7^h\ 20^m$; the lamps were being lighted over London, the hum of London greatly increasing in depth. At this time shouting was heard of people below who saw the balloon; a height of between 1500 and 2500 feet was maintained till $7^h\ 40^m$, the temperature varying from 57° to 54° and dew-point about 47°. The river appeared dull, but the bridges that spanned it, as well as street after street as lighted up, and the miles of lights, sometimes in straight lines, sometimes winding like a serpent, or in some places forming a constellation at some place of amusement, constituted a truly remarkable scene, associated as this appearance was with the deep sound, or rather roar of the traffic of the metropolis.

For a considerable time Kennington Oval and Milbank Penitentiary were in sight, and it seemed as though we could not get away from them. At $7^h\ 40^m$ Mr. Coxwell determined to ascend above the clouds. We were then about 2500 feet high, and the temperature was 53°, dew-point 46°. At $7^h\ 42^m$ a height of 3500 feet was attained, the temperature being 51°. At $7^h\ 47^m$ a height of one mile had been reached, and the temperature was 45°, dew-point 42°. It was very dark below, but there was a clear sky above, and a beautiful gleam of light appeared. We still ascended till the clouds were below us, tinged and coloured with a rich red: the temperature had now fallen to 43°; we were soon enveloped in a fog again. At $7^h\ 52^m$ the striking of a clock and the tolling of a bell were heard. It was quite dark below, but the sun tinged the tops of the clouds. At $8^h\ 5^m$ we were quite above the clouds, and it became light again; the hum of London gradually died away. By this time the temperature had increased to 55°, the barometer reading 23 inches, corresponding to a height of 7400 feet. After this we descended, and it became too dark to read the instruments. London again was seen, very different indeed in its appearance from when we could pick out every square, street, bridge, &c. by its lights; now, as seen through the mist, it had the appearance of a large conflagration of enormous extent, and the sky was lit up for miles around. After a time the lowing of cattle was heard, and we seemed to have left London, so Mr. Coxwell determined to pass through the clouds and examine the country beneath. We passed from the comparative light above to the darkness beneath, momentarily becoming darker, and found ourselves some little distance from London, and shortly afterwards touched the ground, so gently that we were scarcely aware of the contact, in the centre of a field at Mill Hill, about one mile and a half from Hendon, and it was resolved to anchor the balloon for the night, with the view of making an early morning ascent.

Ascent from Mill Hill near Hendon, August 21.—By half-past 4 A.M. the instruments were replaced, and the earth was again left. It was a dull, warm, cloudy morning, still rather dusk, the sky overcast with cirrostratus cloud. The temperature was nearly as high as 61°, and dew-point 59°. There were in the car, besides Mr. Coxwell and myself, Captain Percival, of the Connaught Rangers, Mr. Ingelow, and my son.

We at first rose very slowly; at $4^h\ 38^m$ we were 1000 feet high, and the temperature was 58°, dew-point 56°. At $4^h\ 41^m$ there was a break in the clouds to the east, and a beautiful line of light with gold and silver tints. Here and there, the morning mist was sweeping. At $4^h\ 51^m$ the temperature was 50°, and dew-point 42°; scud was below us, and the cloud of night was in a transition state into cumulus, or the cloud of day, at the same level as we were, viz. about 3500 feet; black clouds were above, and mist was creeping along the ground. At 4^h 55^m we were above a mile high; the temperature was 43°, dew-point 42°; we were just entering cloud. At 4^h 57^m we were in cloud, surrounded by white mist; the temperatures of the air and the dew-point were alike, viz. 39¾°. The light rapidly increased, and gradually we emerged from the dense cloud into a basin surrounded by immense black mountains of cloud rising far above us; shortly afterwards we were looking into deep ravines of grand proportion, bounded with beautiful curved lines. The sky immediately overhead was blue, dotted with cirrus clouds.

As we ascended, the tops of the mountain-like clouds became silvery and golden. At 5^h 1^m we were level with them, and the sun appeared, flooding with golden light all the space we could see for many degrees both right and left, tinting with orange and silver all the remaining space around us. It was a glorious sight. At 5^h 10^m a height of 8000 feet had been attained, and the temperature had increased from 38½° in the cloud to 41°. We still ascended, rather more quickly as the sun's rays fell upon the balloon, each instant opening to us ravines of wonderful extent, and presenting to our view a mighty sea of clouds. Here arose shining masses of cloud in mountain chains, some rising perpendicularly from the plain, dark on one side, and silvery and bright on the other, with summits of dazzling whiteness; some were of a pyramidal form, and a large portion undulatory or wavy, in some places subsiding into hollows, and in one place having the appearance of a huge lake; on the extremity of the horizon snowy peaks bounded the view, resembling Alpine ranges. Nor was the scene wanting in light and shade: each large mass of cloud cast a shadow, and this circumstance, added to the very many tints, formed a beautiful scene. At 5^h 16^m we were nearly two miles high, the temperature was 32°, and dew-point 13°; the air was therefore dry. At 5^h 18^m we were above two miles in height; the temperature was 31°, and dew-point 10°. By 5^h 31^m we were something less than three miles high; the temperature was 23°, and dew-point −15°, and it decreased to 19° by 5^h 34^m. This elevation was maintained for half an hour, during which time the temperature increased 5° or 6° as the sun's altitude increased. Shortly after 6 o'clock it was determined to descend; the temperature, which had been as high as 27°, had fallen to 23°. At 6^h 13^m, at the height of 2¼ miles, we heard a train. At 6^h 20^m we were two miles high, and the temperature had increased to 39°, and dew-point to 19°: at this time I noticed the loud ticking of a watch; Captain Percival said he could not hear it; he was seated, and I was standing; and some experiments were made, when it was found that when the ear was at the same level as the watch, no sound was heard, but it was remarkably distinct on the ear being situated above it.

At the height of two miles the barking of a dog was heard; the temperature at this time (6^h 24^m) was 43°, and dew-point 10° lower. The shadow of the balloon, with an encircling oval of prismatic colours, was here very remarkable, and it increased in dimensions and vividness of colour till we entered a cloud at 6^h 29^m; the increase of temperature, which had been in progress during the descent, was immediately checked, and on emerging from the cloud at 6^h 33^m the temperature was 43°, dew-point 38°. The earth was now in sight, without a ray of sunlight falling upon it. The temperature gradually increased to 56°, and dew-point to 50° at 1000 feet in height, and 62° on reaching the ground, as gently as on the preceding evening, at Dunton Lodge near Biggleswade, on the estate of Lord Brownlow, where we received every attention and assistance from his agent, Mr. Paulger.

Ascent from the Crystal Palace, September 1.—The wind on this day blew from the E.N.E., the sky was almost covered with cirrostratus cloud, but the horizon was moderately clear. The ascent took place at $4^h 40^m$ P.M.; the temperature was 64°; the balloon rose to the height of half a mile in 4 minutes, the temperature decreasing to 51°, and dew-point to 43°; at this time the whole of the River Thames, from its mouth to beyond Richmond, was in sight. At $5^h 31^m$, when we were about 4000 feet high, clouds were observed forming and following the whole course of the Thames, from the Nore up to the higher parts, and extending but little beyond its sides; the clouds were parallel to the river, following all its windings and bendings. The Astronomer Royal has often seen this phenomenon over the part of the river commanded by the Royal Observatory, but it was scarcely expected that clouds throughout its whole course would have formed so simultaneously and uniformly. On referring to the state of the tide, it was found to be just high water at London Bridge about this time, connecting the formation with the warm water from the sea. After $5^h 40^m$ we were higher than all clouds near us, excepting the uniform stratus cloud above us, which we never approached; and it was noted that the upper surface of the lower clouds was bluish white, the middle portion the pure white of the cumulus, and the lowest a blackish white, and from which rain was falling, and, as we afterwards learned, had been falling all the afternoon. We descended to 1300 feet nearly, but were still above the clouds; we then rose to 3000 feet, and rain fell upon the balloon from the upper stratum of cloud, and no difference of temperature from 54° was observed in the stratum between 1300 feet and 3000 feet, although a short time before, in passing downwards through this distance, the temperature had increased from 48° to 54°. The falling rain equalized the temperature. The balloon began to descend after this, and fell at $6^h 15^m$ near Woking in Surrey. The evening looked so unpromising, and rain was still falling, that it was thought unadvisable to fasten the balloon for the night, and attempt a high morning ascent, as was contemplated. In this ascent the observations of the barometers and Daniell's hygrometer were made by Mr. J. MacDonald, Assistant Secretary to the British Meteorological Society.

Ascent from Wolverhampton, September 5.—This ascent had been delayed, owing to the unfavourable state of the weather. It commenced at $1^h 3^m$ P.M.; the temperature of the air was 59°, and the dew-point 50°; at the height of one mile it was 41°, dew-point 38°; and shortly afterwards we entered a cloud of about 1100 feet in thickness, in which the temperature of the air fell to 36½°, the dew-point being the same, thus indicating that the air was here saturated with moisture. On emerging from the cloud at $1^h 17^m$, we came upon a flood of strong sunlight, with a beautiful blue sky, without a cloud above us, and a magnificent sea of cloud below, its surface being varied with endless hills, hillocks, mountain chains, and many snow-white masses rising from it. I here tried to take a view with the camera, but we were rising with too great rapidity, and going round and round too quickly to enable me to do so; the flood of light, however, was so great, that all I should have needed would have been a momentary exposure, as Dr. Hill Norris had kindly furnished me with extremely sensitive dry plates for the purpose. We reached two miles in height at $1^h 21^m$; the temperature had fallen to the freezing-point, and the dew-point to 26°. We were three miles high at $1^h 28^m$, with a temperature of 18°, and dew-point 13°; at $1^h 39^m$ we had reached four miles, and the temperature was 8°, and dew-point −15°; in ten minutes more we had reached the fifth mile, and the temperature had passed below zero, and then read

— 2°, and at this point no dew was observed on Regnault's hygrometer when cooled down to — 30°; but a dew-point obtained from the readings of dry and wet gave —36°. Up to this time I had taken observations with comfort. I had experienced no difficulty in breathing, whilst Mr. Coxwell, in consequence of the necessary exertions he had to make, had breathed with difficulty for some time. At 1ʰ 51ᵐ the barometer reading was 11·05 inches, but which requires a subtractive correction of 0·25 inch, as found by comparison with Lord Wrottesley's standard barometer just before starting. I afterwards read the dry thermometer as —5°; this must have been about 1ʰ 52ᵐ or later; I could not see the column of mercury in the wet-bulb thermometer; nor afterwards the hands of the watch, nor the fine divisions on any instrument. I asked Mr. Coxwell to help me to read the instruments, as I experienced a difficulty in seeing. In consequence, however, of the rotatory motion of the balloon, which had continued without ceasing since the earth had been left, the valve-line had become twisted, and he had to leave the car and mount into the ring above to adjust it. At this time I looked at the barometer, and found it to be 10 inches, still decreasing fast; its true reading therefore was 9¾ inches, implying a height of 29,000 feet. Shortly afterwards I laid my arm upon the table, possessed of its full vigour, and on being desirous of using it, I found it powerless—it must have lost its power momentarily. I tried to move the other arm, and found it powerless also. I then tried to shake myself, and succeeded in shaking my body. I seemed to have no limbs. I then looked at the barometer, and whilst doing so my head fell on my left shoulder. I struggled and shook my body again, but could not move my arms. I got my head upright, but for an instant only, when it fell on my right shoulder, and then I fell backwards, my back resting against the side of the car, and my head on its edge; in this position my eyes were directed towards Mr. Coxwell in the ring. When I shook my body I seemed to have full power over the muscles of the back, and considerable power over those of the neck, but none over either my arms or my legs; in fact I seemed to have none. As in the case of the arms, all muscular power was lost in an instant from my back and neck. I dimly saw Mr. Coxwell in the ring, and endeavoured to speak, but could not; when in an instant intense black darkness came, the optic nerve finally lost power suddenly. I was still conscious, with as active a brain as at the present moment whilst writing this. I thought I had been seized with asphyxia, and that I should experience no more, as death would come, unless we speedily descended: other thoughts were actively entering my mind, when I suddenly became unconscious as on going to sleep. I cannot tell anything of the sense of hearing; the perfect stillness and silence of the regions 6 miles from the earth (and at this time we were between 6 and 7 miles high) is such that no sound reaches the ear.

My last observation was made at 1ʰ 54ᵐ at 29,000 feet. I suppose two or three minutes fully were occupied between my eyes becoming insensible to seeing fine divisions and 1ʰ 54ᵐ, and then that two or three minutes more passed till I was insensible, therefore I think this took place at about 1ʰ 56ᵐ or 1ʰ 57ᵐ. Whilst powerless I heard the words "Temperature" and "Observation," and I knew Mr. Coxwell was in the car speaking to me, and endeavouring to arouse me, therefore consciousness and hearing had returned. I then heard him speak more emphatically, but I could not see, speak, or move. I heard him again say, "Do TRY—NOW DO." Then I saw the instruments dimly, then Mr. Coxwell, and very shortly saw clearly. I rose in my seat and looked round, as though waking from sleep, though not refreshed by sleep, and said to Mr. Coxwell, "I have been insensible;" he said, "You have; and I, too, very nearly." I then drew up my legs, which had been extended before me, and took a pencil in my hand to begin observations. Mr. Coxwell told me that he had lost the use of his hands, which were black, and I poured brandy over them.

I resumed my observations at 2h 7m, recording the barometer reading at 11·53 inches and temperature — 2°. I suppose that three or four minutes were occupied from the time of my hearing the words "temperature" and "observation" till I began to observe; if so, then returning consciousness came at 2h 4m, and this gives seven minutes for total insensibility. I found the water in the vessel supplying the wet-bulb thermometer, which I had by frequent disturbances kept from freezing, was one solid mass of ice; and it did not all melt until after we had been on the ground some time.

Mr. Coxwell told me that whilst in the ring he felt it piercingly cold; that hoar-frost was all round the neck of the balloon; on attempting to leave the ring, he found his hands frozen, and he had to place his arms on the ring and drop down; that he thought for a moment I had laid back to rest myself; that he spoke to me without eliciting a reply; that he then noticed my legs projected and my arms hung down by my side; that my countenance was serene and placid, without the earnestness and anxiety he had noticed before going into the ring, and then it struck him I was insensible. He wished to approach me, but could not, and he felt insensibility coming over himself; that he became anxious to open the valve, but in consequence of having lost the use of his hands he could not, and ultimately did so by seizing the cord with his teeth and dipping his head two or three times until the balloon took a decided turn downwards. This act is quite characteristic of Mr. Coxwell. I have never yet seen him without a ready means of meeting every difficulty as it has arisen, with a cool self-possession that has always left my mind perfectly easy, and given me every confidence in his judgment in the management of so large a balloon.

No inconvenience followed this insensibility, and when we dropped it was in a country where no conveyance of any kind could be obtained, so that I had to walk between seven and eight miles.

The descent was at first very rapid; we passed downwards three miles in nine minutes; the balloon's career was then checked, and finally descended in the centre of a large grass field belonging to Mr. Kersall, at Cold Weston, seven and a half miles from Ludlow.

I have already said that my last observation was made at a height of 29,000 feet; at this time (1h 54m) we were ascending at the rate of 1000 feet per minute, and when I resumed observations we were descending at the rate of 2000 feet per minute; these two positions must be connected, taking into account the interval of time between, viz. 13 minutes, and on these considerations the balloon must have attained the altitude of 36,000 or 37,000 feet. Again, a very delicate minimum thermometer read —12°, and this would give a height of 37,000 feet; Mr. Coxwell on coming from the ring noticed that the centre of the aneroid barometer, its blue hand, and a rope attached to the car, were all in the same straight line, and this gave a reading of 7 inches, and leads to the same result. Therefore these independent means all lead to about the same elevation, viz. fully 7 miles.

In this ascent six pigeons were taken up. One was thrown out at the height of three miles, when it extended its wings and dropped as a piece of paper; a second, at four miles, flew vigorously round and round, apparently taking a dip each time; a third was thrown out between four and five miles, and it fell downwards as a stone. A fourth was thrown out at four miles on descending; it flew in a circle, and shortly alighted on the top of the balloon. The two remaining pigeons were brought down to the ground. One was found to be dead; and the other, a carrier, was still living, but would not leave the hand when I attempted to throw it off, till after a quarter of an hour it began to peck a piece of ribbon which encircled its neck, and was then jerked off the finger, and flew with some vigour towards Wolverhampton. One of the pigeons returned to Wolverhampton on Sunday the 7th, and is the only one that has been heard of.

Ascent from the Crystal Palace, September [illegible].—The sky was for the most part obscured by clouds; the ascent took place at [illegible] p.m., the temperature on the ground being [illegible]; at [illegible] we were half a mile high, with a temperature of [illegible], and dew-point [illegible]; at [illegible] we reached the clouds, with a temperature of [illegible], dew-point [illegible], at the height of [illegible] feet; we rose to [illegible] feet, were still in the cloud, and then fell, passing out of the cloud downwards at [illegible], with a temperature of [illegible], and dew-point 46°; we descended to [illegible] feet by [illegible], where the temperature was 52°, dew-point [illegible]; we then ascended and again reached the cloud at a little over 4200 feet, and with the same temperature as before, viz. [illegible]; we passed out of the cloud at a little over [illegible] feet, into a basin with blue sky above, and the sun shone beautifully; the balloon rose quickly, and the temperature increased from [illegible] on leaving the cloud to [illegible] at a mile in height, and to 59° and dew-point [illegible] at [illegible] feet; we then descended, met with the cloud again at [illegible], at the height of [illegible] feet nearly, and experienced a temperature of [illegible], dew-point [illegible], whilst passing through it; we left the cloud at [illegible] feet high, and the temperature rose from [illegible] to 61°, dew-point to 59°, at the height of [illegible] feet, and to [illegible] at the height of [illegible] feet, where we were at [illegible]; at this time we were crossing the River Thames near to Gravesend, and we passed from bank to bank in [illegible] seconds; we then rose to nearly half a mile, and passed Tilbury Fort at the distance of 2 miles, and with a telescope I examined the fort, and could have drawn its plan and counted any guns within it. We fell at about 4 miles from the Fort, at $6^h\ 10^m$ p.m.

In this ascent Mr. W. C. Nash, of the Magnetical and Meteorological Department of the Royal Observatory, Greenwich, took the observations of the barometer and Daniell's hygrometer.

§ 3. Description of the Table of Observations.

All the meteorological observations taken during the ascents are contained in Table 1.

Column 1 contains the times at which the observations were made. Column 2 contains observations of the siphon barometer corrected for temperature and index error. Column 3 contains the readings of the thermometer attached to the barometer. Column 4 contains the readings of an aneroid barometer. Column 5 contains the height above the level of the sea, as deduced from the barometric observations in column 2, by the formula of Baily, checked at intervals by that of Laplace, which is as follows:—

$$Z=\log\left(\frac{h}{h'}\right)\times 60159\left(1+\frac{t+t'-64}{900}\right)\left(1+0\cdot002837\cos L\right)\left(1+\frac{Z+52251}{20886900}\right),$$

where Z is the height required, and h, h', t and t' the height of the barometer corrected for temperature, and the temperature of the air at the lower and upper stations respectively, L the latitude. The temperature of the air for the position of the balloon has been derived from the readings in column 10. Columns 6 to 9 contain the observations with the dry- and wet-bulb thermometers free, and the deduced dew-point. Column 10 contains the readings of Negretti and Zambra's gridiron thermometer. Columns 11 to 14 contain the observations with the dry- and wet-bulb thermometers aspirated, and the deduced dew-point. Columns 15 and 16 contain the direct dew-point observations with Daniell's and Regnault's hygrometers. When numbers are entered in columns 15 and 16 with "no dew" affixed to them, it is meant that the temperature of the hygrometer has been lowered to the degree stated, but that no dew has been deposited.

Many observers in different parts of the country made observations at short intervals for several hours together, on several days of which notice had been given them that the ascent would take place, but, in consequence of the frequent delays owing to bad weather, their observations were not available, and it was found impossible to give notice with any certainty of the days of ascents.

A good many observers did, however, take a few observations in different parts of the country on the days of the several ascents. The Astronomer Royal at the Royal Observatory, Greenwich, had observations taken every 10 minutes on all the days of ascent, and Lord Wrottesley always arranged to have observations made at Wrottesley by Mr. Hough, on those days when the ascent took place from Wolverhampton. In calculating the height of the balloon, the observations of Wrottesley have been employed for July 17, August 18, and September 5; and those of the Royal Observatory, Greenwich, have been used for July 30, August 20, August 21, Sept. 1, and Sept. 8.

The height of Greenwich above the mean sea-level=159 feet.

The height of Wrottesley above the mean sea-level=531 feet.

TABLE I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	9 42 0 a.m.	29·193	50·0	......	490	59·0	55·0
	9 47 0 „	26·014	44·0	......	3,835	45·0	40·5
(2)	9 49 0 „	25·215	44·0	25·32	4,467	43·0	38·0
(3)	9 51 0 „	24·138	43·5	24·30	5,802	35·8	34·2
(4)	9 53 0 „	22·421	43·0	22·65	7,980	......	......
	9 54 0 „	22·023	42·0	22·20	8,065	32·5	32·0
(5)	9 55 0 „	21·575	41·0	21·80	8,809	30·2	27·7
	9 56 0 „	20·927	40·5	21·10	9,598	28·2	26·1
	9 58 0 „	19·629	40·0	20·09	11,312	......	......
(6)	10 2 0 „	19·281	39·5	19·60	11,792	28·2	27·1
(7)	10 3 0 „	18·633	39·2	18·90	12,709	......	......
(8)	10 4 0 „	......	......	......	......	27·2	25·1
(9)	10 5 0 „	18·136	37·0	18·40	13,467	29·0	28·1
(10)	10 8 0 „	17·235	38·2	17·52	14,544	33·0	30·0
(11)	10 11 0 „	16·735	38·5	17·10	15,704	33·0	30·2
(12)	10 15 0 „	16·036	38·0	16·25	16,914	33·0	30·1
(13)	10 25 0 „	14·937	38·0	15·15	18,844	35·0	31·5
(14)	10 27 0 „	14·637	38·0	15·30	19,374	34·2	31·1
(15)	10 29 0 „	14·637	38·0	15·30	19,415	37·5	30·0
(16)	10 30 0 „	14·637	38·0	15·30	19,415	38·1	31·2
(17)	10 35 0 „	14·637	40·0	15·00	19,435	43·0	31·0
(18)	10 39 0 „	14·634	40·0	......	19,380	37·0	31·5
(19)	10 44 0 „	14·633	40·0	15·10	19,336	36·2	30·5
(20)	10 47 0 „	14·134	40·0	14·70	20,238	32·0	26·5
	10 48 0 „	......	......	......	......	......	......
(21)	10 50 0 „	13·637	39·0	14·20	21,059	24·5	17·2
(22)	10 54 0 „	13·137	39·0	13·60	21,792	19·2	11·2
(23)	10 57 0 „	12·139	38·0	12·60	23,949	16·5	9·5
(24)	11 0 0 „	11·741	37·0	......	24,746	......	......
(25)	11 1 0 „	11·143	36·0	......	26,177	......	......
(26)	11 3 0 „	11·642	35·0	12·10	25,022	......	......
	11 5 0 „	11·644	34·0	......	25,028		
	11 7 0 „	11·645	33·0	12·10	25,077	19·0	9·0
(27)	11 12 0 „	11·945	33·0	12·40	24,547	......	......
(28)	11 20 0 „	12·645	33·0	13·20	23,868	26·1	19·2
	1.	2.	3.	4.	5.	6.	7.

NOTES AND GENERAL

(1) 9

(1) $9^h\ 42^m$, turned tap for water to run; $9^h\ 43^m$, balloon left the earth; $9^h\ 44^m$, dropped gutta-percha tubes below the car. (2) Clouds reached.

(3) Clouds at a lower elevation all round. (4) In a cloud, cumulostratus; dry; fog.

(5) Sun shining on the balloon; valve opened; beautiful view.

(6) Clouds beautiful; balloon full. (7) Band of music heard.

(8) Earth visible. (9) Electrometer, balloon reading 59°; air reading 64°.

(10) Electrometer, balloon reading 59°; air reading 63°.

(11) Electrometer, balloon reading 59°; air reading 63°.

(12) Gas cleared in balloon from appearance of smoke to transparency; intense prussian blue sky; cumuli clouds far below; strati same height; no clouds above.

(13) Eighteen vibrations of horizontal magnet occupied $26^s·8$. Mr. Coxwell's pulse 84; Mr. Glaisher's 100; Mr. Coxwell's 86. (14) Wind S.W.; moving N.E.

(15) Palpitation of heart perceptible in both of us; clock beat very loud; breathing affected. (16) Ozone 0. Tried to take vibrations.

Balloon Ascents. Wolverhampton, July 17, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
4·0	51·4							
4·5	35·3							
5·0	32·0	43·0						
1·6	33·8	34·8	……	……	……	……	30·5	
……	……	32·5						
0·5	27·8							
2·5	19·7	29·8	……	……	……	……	……	24·0
2·1	17·6	26·2						
……	……	26·0	……	……	……	……	24·5	
1·1	23·9	26·0	……	……	……	……	……	25·0
……	……	26·0	……	……	……	……	19·5	21·0
2·1	16·9	26·2	……	……	……	……	21·0	22·0
0·9	24·9	……	……	……	……	……	……	22·5
3·0	24·0	31·0	32·0	30·4	1·6	26·7	20·5	24·0
2·8	24·6	31·6	32·0	29·2	0·8	22·7	22·0	21·5
2·9	24·3	32·0	31·0	28·0	3·0	19·8	23·0	20·8
3·5	24·9	37·2	35·0	31·2	3·8	24·4	25·1	24·2
3·1	25·6	36·1	36·5	31·2	5·3	23·2	22·6	21·0
7·5	19·5	38·2	37·0	30·5	6·5	21·4	……	22·2
6·9	21·8	38·1	37·5	29·5	8·0	18·3	21·5	22·2
12·0	16·6	42·2	……	……	……	……	19·0	20·0
5·5	23·8	36·5	34·5	……	……	……	20·0	21·1
5·7	22·1	34·0	36·2	30·5	5·7	22·1	20·5	20·5
5·5	13·8	31·5	30·8	26·0	4·8	13·2	16·0	15·5
……	……	31·0						
7·3	−26·6	……	23·0	17·0	6·0	−20·6	−12·0	−13·0
8·0	−47·5	……	……	……	……	……	− 8·2	
7·0	−44·1	17·5	18·5	8·0	10·5	−69·9	……	− 9·0
……	……	16·0	……	……	……	……	……	− 8·0
……	……	16·0	……	……	……	……	− 9·0	
……	……	16·0	……	……	……	……	……	− 8·5
10·0	−67·4	……	18·2	12·0	6·2	−34·5		
……	……	23·7						
6·9	−25·8	27·0						
8.	9.	10.	11.	12.	13.	14.	15.	16.

Remarks.

(17) Electrometer, balloon reading 58°; air reading 61°. Palpitation of heart very perceptible.

(18) Deep blue sky; dark bluish hands and lips, not face.

(19) Sand out. Electrometer, balloon reading 58°; air reading 60°·2. Heart less affected; moving northwards.

(20) Twenty-eight vibrations of horizontal magnet occupied 43^{s}.

(21) Electrometer, balloon reading 59°; air reading 58°. Breathing affected.

(22) No dew at −8°·2. Electrometer, balloon reading 58°; air reading 59°. Very deep blue sky; clouds far below; cold, but not intense. (23) No dew. All the feelings of sea-sickness.

(24) Ozone 0. Feeling of illness. Mr. Coxwell says a disagreeable sensation came over him; cannot tell how. (25) No dew at this temperature.

(26) No dew. Through a feeling of illness, I was unable to keep to the instruments long enough to lower the temperature to get a deposit of dew.

(27) Electrometer, balloon reading 58°; air reading 58°. (28) Ozone 0; the air is very dry.

Table I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	11 25 0 a.m.	13·144	......	13·60	22,357	28·1	17·5
(2)	11 37 0 „	16·359	33·0	......	16,282	29·7	24·8
(3)	11 38 0 „	18·944	......	19·00	12,376	34·2	28·1
(4)	11 39 0 „	20·042	......	20·40	10,539	37·0	?
(5)	11 40 0 „	20·542	......	20·80	9,882	37·8	30·2
(6)	11 42 0 „						
(7)	11 44 0 „	23·442	......	......	6,330		
(8)	11 45 0 „	24·242	......	......	5,432		
Crystal Palace, July 30, 1862.							
(9)	4 36 0 p.m.	......	......	29·96	250	68·2	58·0
(10)	4 40 0 „	......	......	29·96	250	68·0	57·8
(11)	4 40 30 „	......	......	29·87	330	67·2	56·5
	4 40 45 „	......	......	29·82	370	66·5	56·2
	4 41 0 „	......	......	29·80	390	66·5	56·2
(12)	4 41 15 „	......	......	29·65	480	66·0	56·0
	4 41 30 „	......	......	29·55	570	65·5	55·5
	4 42 0 „	......	......	29·50	615	65·2	54·1
	4 42 30 „	......	......	29·20	890	63·8	53·5
	4 43 0 „	......	......	28·85	1,189	62·0	51·9
	4 43 30 „	......	......	28·65	1,389	62·0	51·8
	4 44 30 „	......	......	28·20	1,829	59·8	51·1
(13)	4 45 30 „	......	......	27·65	2,379	58·5	50·1
	4 47 30 „	......	......	27·10	2,452	54·2	48·0
	4 48 30 „	......	......	26·87	3,161	52·5	47·0
	4 49 0 „	......	......	26·50	3,540	51·0	45·5
	4 50 0 „	......	......	26·40	3,640	50·4	45·5
	4 50 30 „	......	......	26·35	3,690	49·8	45·5
	4 52 0 „	......	......	26·27	3,770	50·0	45·0
	4 52 30 „	......	......	26·25	3,790	50·6	45·7
	4 53 30 „	......	......	26·18	3,860	51·0	45·6
	4 54 0 „	......	......	26·12	3,920	52·2	46·0
	4 54 30 „	......	......	26·08	3,960	52·5	46·0
(14)	4 56 0 „	......	......	25·91	4,169	51·5	46·0
	4 56 45 „	......	......	25·80	4,279	50·0	45·0
	4 57 30 „	......	......	25·73	4,358	50·5	45·0
	4 59 0 „	......	......	25·78	4,308	50·5	45·0
	4 59 30 „	......	......	25·85	4,234	51·5	46·0
	5 0 0 „	......	......	25·90	4,184	51·8	46·0
	5 0 30 „	......	......	26·90	4,084	51·8	46·0
(15)	5 1 0 „	......	......	......	(4,094)	51·5	45·8
	1.	2.	3.	4.	5.	6.	7.

(1) Could not get the magnet to vibrate; ozone 0.

(2) Tried for some time to get vibrations; arcs of 20°; settled immediately; ozone 0 (ill again).

(3) Image of balloon and car on cloud very large and distinct.

(4) Sand out.

(5) Passing through cloud; could not see the balloon.

(6) Fog; dry.

(7) Sand out; balloon forming a parachute.

(8) Clouds of a dense character were rising apparently with great rapidity. The balloon was descending very quickly; I hurriedly put up as many instruments as I could.

Balloon Ascents. Wolverhampton, July 17, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
10·6	−26·1	27·2	……	16·2				
4·9	+ 9·4							
6·1	7·4							
7·6	19·9	……	37·8	30·1	7·7	19·7		

Crystal Palace, July 30, 1862.

10·2	50·0	……	……	……	……	……	50·0	
10·2	49·7							
10·7	48·0							
10·3	47·9							
10·3	47·9							
10·0	47·9							
10·0	47·3							
11·1	45·1							
10·3	44·9	……	……	……	……	……	44·0	
10·1	43·2							
10·2	43·0							
8·7	43·5							
8·4	42·6	……	……	……	……	……	38·5	
6·2	41·9							
5·5	41·4							
5·5	39·8							
4·9	40·4							
4·3	41·0	……	……	……	……	……	36·3	
5·0	39·7	……	……	……	……	……	40·5	
4·9	40·7	……	……	……	……	……	41·5	
5·4	40·0							
6·2	39·7							
6·5	39·4							
5·5	40·3	……	……	……	……	……	41·5	
5·0	39·7	……	……	……	……	……	41·2	
5·5	39·2							
5·5	39·2							
5·5	40·3							
5·8	40·1							
5·8	40·1							
5·7	39·9							
8.	9.	10.	11.	12.	13.	14.	15.	16.

Mr. Coxwell discharged quickly several bags of ballast; let go the grapnel, and called out to me to take hold, when the car struck the earth with great violence, which broke several instruments; then bounded and descended again, and finally the balloon-netting caught in a large tree at 11h 50m, at Langham, near Oakham.

(9) Thirteen in car. Raised a little for photograph. (10) Left at 4h 40m 10s.
(11) Sand out. (12) Wind S.W. (13) Gas cloudy.
(14) Thin fog; horizon hidden; hazy. (15) Sand out.

TABLE I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther.	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	5 1 30 p.m.	......	......	25·98	4,104	52·1	46·2
	5 3 0 „	......	......	25·76	4,324	51·5	46·2
(2)	5 4 30 „	......	......	25·68	4,403	52·1	46·0
	5 7 30 „	......	......	25·47	4,613	49·2	43·1
	5 8 0 „	......	......	25·30	4,783	49·0	43·1
(3)	5 9 30 „	......	......	25·40	4,683	48·5	43·5
	5 10 0 „	......	......	25·35	4,733	48·9	43·5
(4)	5 11 30 „	......	......	25·20	4,923	48·2	43·1
	5 12 0 „	......	......	25·20	4,923	48·5	43·1
	5 14 0 „	......	......	25·26	4,863	48·2	43·0
	5 16 0 „	......	......	25·25	4,873	48·2	43·3
(5)	5 16 30 „	......	......	25·20	4,923	47·9	43·0
(6)	5 17 30 „	......	......	25·00	5,155	49·5	43·1
	5 18 0 „	......	......	24·93	5,220	49·3	43·5
	5 20 30 „	......	......	24·78	5,370	48·2	43·0
	5 21 0 „	......	......	24·79	5,360	48·5	43·1
	5 22 0 „	......	......	24·95	5,200	49·8	44·5
	5 23 30 „	......	......	24·95	5,200	48·5	43·1
	5 24 0 „	......	......	24·82	5,330	50·0	44·5
(7)	5 24 30 „	......	......	24·70	5,450	47·5	42·0
(8)	5 26 0 „	......	......	24·62	5,830	47·8	42·1
	5 28 30 „	......	......	24·32	5,530	48·0	42·0
(9)	5 31 0 „	......	......	24·47	5,380	48·5	42·6
(10)	5 31 30 „	......	......	24·57	5,280	48·2	43·5
(11)	5 38 30 „	......	......	24·30	5,903	43·5	40·0
(12)	5 39 0 „	......	......	24·22	5,983	43·5	40·0
(13)	5 40 30 „	......	......	24·02	6,183	43·5	40·0
	5 41 0 „	......	......	......	(6,220)	44·1	39·5
	5 43 0 „	......	......	23·83	6,370	44·2	38·9
(14)	5 44 0 „	......	......	24·00	6,252	45·2	40·5
	5 45 30 „	......	......	24·42	5,785	46·5	41·5
(15)	5 47 0 „	......	......	24·60	5,577	46·0	41·5
	5 48 0 „	......	......	24·53	5,649	45·2	40·5
	5 50 0 „	......	......	24·35	5,846	44·2	39·8
(16)	5 52 0 „	......	......	24·12	6,102	43·0	38·5
(17)	5 54 0 „	......	......	23·82	6,466	46·0	40·5
	5 55 0 „	......	......	23·69	6,642	46·5	40·5
	5 57 0 „	......	......	23·58	6,752	47·2	41·5
	5 57 30 „	......	......	23·50	6,826	43·5	38·0
	5 58 0 „	......	......	23·47	6,856	43·1	37·9
	5 58 30 „	......	......	23·43	6,896	43·5	38·0
	5 59 0 „	......	......	......	(6,910)	43·0	37·0
	6 0 0 „	......	......	23·40	6,937	42·5	37·0
	6 1 0 „	......	......	23·47	6,867	41·0	37·0
(18)	6 2 0 „	......	......	23·79	6,547	41·5	37·0
(19)	6 6 0 „	......	......	......	(6,603)	45·6	39·1
	1.	2.	3.	4.	5.	6.	7.

(1) Balloon spirating.
(2) Between these two intervals tried to get magnet to vibrate, but could not do so.
(3) Misty and thick to leeward; fine to windward.
(4) Twenty vibrations of horizontal magnet in 32s·5. Needle kept in same relative position to the car. (5) Sand out. (6) Wind W.N.W.
(7) Gun heard with a sharp sound; drum beating; band heard.
(8) Cumuli all round at lower elevation. (9) Gas partially clear.

Balloon Ascents. Crystal Palace, July 30, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
5·9	40·2	......	......	......	......	......	43·1	
5·3	40·7	......	......	......	......	......	43·1	
6·1	39·8	......	......	......	......	......	41·0	
6·2	36·5	......	......	......	......	......	40·5	
5·9	36·7							
5·0	38·1	......	......	......	......	......	39·5	
5·4	37·7							
5·1	37·5							
5·4	37·2							
5·2	37·3	......	......	......	......	......	39·5	
4·9	38·0	......	......	......	......	......	39·0	
4·9	37·6	......	......	......	......	......	39·5	
6·4	36·2							
5·8	37·3	......	......	......	......	......	39·0	
5·2	37·3							
5·4	37·2	......	......	......	......	......	40·5	
5·3	38·9	......	......	......	......	......	40·0	
5·4	37·2	......	......	......	......	......	42·0	
5·5	38·7	......	......	......	......	......	40·2	
5·5	35·9	......	......	......	......	......	38·0	
5·7	35·8	......	......	......	......	......	38·2	
6·0	35·4	......	......	......	......	......	36·2	
5·9	36·2							
4·7	38·4	......	......	......	......	......	36·5	
3·5	35·8							
3·5	35·8	......	......	......	......	......	38·0	
3·5	35·8							
4·6	34·0	......	......	......	......	......	36·0	
6·3	32·7	......	......	......	......	......	34·0	
4·7	35·1							
5·0	35·9							
4·5	36·4	......	......	......	......	......	36·0	
4·7	35·1							
4·4	34·7	......	......	......	......	......	35·5	
4·5	33·1	......	......	......	......	......	36·0	
5·5	34·3							
6·0	33·8							
5·7	35·2							
5·5	31·4							
5·2	32·6							
5·5	31·4							
6·0	29·8							
5·5	30·3	......	......	......	......	......	32·0	
4·0	32·0	......	......	......	......	......	31·5	
4·5	31·4	......	......	......	......	......	32·0	
6·5	31·6							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(10) Deep blue sky, dotted with cumuli; sun shining brightly.
(11) Misty; cloudy particles moving; gun heard.
(12) Balloon spirating. (13) Wind N.
(14) Sun shining on cases of Dry and Wet Bulb Thermometers; readings not affected thereby.
(15) Cloudy particles seen moving. (16) Sun shining on Daniell's Hygrometer. (17) Great mist.
(18) Deep blue sky, dotted with cirrocumuli, cumuli, and cumulostratus below.
(19) Ozone 0; steamboat seen near Dartford.

TABLE I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	6 7 0 p.m.	......	......	......	(6,617)	45·2	39·5
(2)	6 7 30 „	......	......	......	(6,625)	45·0	39·2
	6 8 30 „	......	......	23·70	6,637	45·0	38·6
	6 10 30 „	......	......	23·59	6,747	44·8	37·5
	6 11 30 „	......	......	23·40	6,937	44·2	38·5
(3)	6 13 0 „	......	......	23·42	6,917	44·2	38·5
	6 14 0 „	......	......	......	......	44·5	38·2
	6 15 0 „	......	......	23·63	6,720	44·5	38·9
	6 17 0 „	......	......	......	......	45·5	39·0
	6 18 0 „	......	......	23·95	6,400	45·2	38·9
	6 18 30 „	......	......	24·35	6,000	46·4	40·0
	6 19 0 „	......	......	24·55	5,800	46·0	40·5
	6 19 30 „	......	......	24·60	5,750	46·2	41·5
(4)	6 20 0 „	......	......	24·95	5,400	47·0	41·5
	6 21 0 „	......	......	25·40	4,950	47·5	42·5
	6 22 0 „	......	......	25·90	4,450	47·8	43·5
	6 22 30 „	......	......	......	......	49·0	44·0
(5)	6 23 0 „	......	......	26·48	3,870	49·2	44·5
	6 24 0 „	......	......	26·60	3,750	50·1	46·0
	6 25 0 „	......	......	27·65	2,700	55·5	48·7
	6 25 30 „	......	......	......	......	58·3	49·5
(6)	6 30 0 „	......	......	29·96	on the ground	68·0	56·5

Wolverhampton, August 18, 1862.

(7)	0 53 0 p.m.	29·342	69·0	......	490	......	......
(8)	0 56 0 „	29·342	69·0	29·51	490	66·2	60·0
(9)	1 5 0 „	28·842	......	......	1,130	62·5	57·1
	1 6 0 „	28·546	......	28·78	1,419	......	......
	1 6 20 „	28·247	......	......	1,713	58·2	55·5
	1 6 30 „	......	......	......	......	......	......
	1 7 0 „	27·898	......	......	2,042	55·1	53·8
(10)	1 8 0 „	26·665	64·5	26·90	3,347		
(11)	1 8 20 „	......	......	......	......	......	......
(12)	1 9 0 „	26·271	......	......	3,705	50·0	49·8
	1 10 0 „	25·862	62·0	26·08	4,138	......	......
	1 10 25 „	......	......	......	......	49·8	47·1
	1 11 0 „	25·300	61·0	......	4,767	48·8	45·6
(13)	1 11 30 „	......	......	25·15	(5,140)	......	......
	1 12 0 „	24·600	59·5	......	5,509	......	......
	1 12 30 „	24·602	......	......	5,510	47·8	45·5
	1 13 20 „	......	......	......	......	......	......
(14)	1 14 0 „	23·635	59·0	23·82	6,585	......	......
	1.	2.	3.	4.	5.	6.	7.

(1) Cumulostratus and cumulus same height; strati above.
(2) Ozone 0, by Moffat and Schönbein. (3) Going down Long Reach. (4) Gravesend.
(5) Removed instruments; hop-garden under us; came down in potato-field.

(6) In this ascent the instruments were carried by a board fixed to the side of the car of the balloon, I standing all the time and looking over the side of the car; Mr. Ingelow was seated on my left hand and read the Aneroid Barometer and Daniell's Hygrometer; my son was on my right hand.

Balloon Ascents. Crystal Palace, July 30, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
5·7	32·9							
5·8	32·4							
6·4	31·3							
7·3	29·0							
5·7	31·8	......	......	......	......	......	32·0	
5·7	31·8	......	......	......	......	......	32·0	
6·3	30·8	......	......	......	......	......	31·8	
5·6	32·4							
6·5	32·5							
6·3	32·7	......	......	......	......	......	31·0	
6·4	32·8	......	......	......	......	......	32·0	
5·5	34·3							
4·7	36·2							
5·5	35·4							
5·0	37·0	......	......	......	......	......	39·0	
4·3	38·8	......	......	......	......	......	40·0	
5·0	38·6							
4·7	39·5							
4·1	41·7							
7·8	42·2	......	......	......	......	......	42·5	
9·8	41·7							
11·5	47·4							
Wolverhampton, August 18, 1862.								
......	......	......	65·0	57·5	7·5	51·4		
6·2	55·0	67·8	68·0	60·5	7·5	54·6	55·0	53·9
5·4	52·5							
......	......	60·0						
2·7	53·1							
......	......	57·2						
1·3	52·5	......	56·0	53·2	2·4	50·6	......	48·5
......	......	52·5						
0·2	49·6							
......	......	49·9						
2·7	44·2							
3·2	42·2							
......	......	48·6						
......	......	48·2						
4·3	38·8							
......	......	......	48·0	44·1	3·9	39·8	37·0	36·2
......	......	46·5						
8.	9.	10.	11.	12.	13.	14.	15.	16.

(7) In car of balloon before starting.

(8) In car of balloon.

(9) Wind N.N.E.; left the earth at 1h 2m 38s.

(10) In cumulus cloud.

(11) Lost sight of earth.

(12) Sun glorious and beautiful indeed; deep blue sky.

(13) Over railway; exceedingly beautiful.

(14) Going towards Birmingham; over Black Country.

TABLE I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	1 15 0 p.m.	22·687	59·0	22·68	7,706	......	......
(2)	1 17 0 ,,	21·694	57·0	......	8,935	44·0	38·5
(3)	1 18 45 ,,	20·895	57·0	......	9,954	43·5	37·0
(4)	1 18 55 ,,	......	......	20·89	......	41·0	35·5
	1 20 0 ,,	19·897	......	20·05	11,267	......	......
(5)	1 20 5 ,,	......	......	......	......	37·2	32·1
	1 20 35 ,,	19·797	......	......	11,399	36·0	31·5
(6)	1 21 0 ,,	19·749	......	......	11,470	39·5	32·0
(7)	1 22 0 ,,	20·297	......	......	10,840	42·0	36·0
(8)	1 24 0 ,,	20·897	......	......	9,884	45·0	38·0
	1 24 5 ,,	......	......	......	......	......	......
	1 24 15 ,,	20·897	......	21·28	9,884		
	1 24 50 ,,	21·377	......	......	......	46·2	39·5
(9)	1 25 0 ,,	......	......	21·80	......	......	......
	1 25 10 ,,	......	......	......	......	47·2	40·5
	1 26 0 ,,						
	1 26 30 ,,	22·212	......	......	8,342	......	......
(10)	1 27 0 ,,	22·622	52·0	22·90	7,836	51·0	46·5
	1 32 0 ,,	22·802	......	22·85	7,650	51·2	46·0
(11)	1 33 0 ,,	22·802	......	......	7,650	53·8	47·8
(12)	1 34 0 ,,	......	......	......	......	......	......
(13)	....	......	......	......	......	......	......
(14)	1 37 30 ,,	24·248	59·0	......	5,919	56·8	50·5
(15)	1 38 0 ,,	24·460	59·0	24·60	5,820	57·0	50·5
	1 39 0 ,,						
	1 40 0 ,,	......	......	......	......	58·0	51·5
	1 41 0 ,,	25·083	62·0	25·30	5,028	58·9	52·0
(16)	1 41 30 ,,	25·564	65·0	......	4,530	......	......
	1 42 0 ,,	......	......	25·60			
(17)	1 43 0 ,,	25·584	......	......	4,480	60·0	53·5
	....	......	......	......	......	60·9	53·5
(18)	1 46 0 ,,	26·561	......	......	3,438	61·0	53·5
(19)	1 48 0 ,,	26·756	67·0	......	3,219	59·0	54·0
	1 52 0 ,,	25·795	......	25·82	4,233	53·5	49·2
(20)	1 52 30 ,,	25·594	65·0	......	4,448		
	1 53 0 ,,	......	......	......	......	52·2	48·5
	1 55 0 ,,	25·079	65·0	25·25	5,019	51·0	47·8
(21)	1 56 0 ,,	......	......	......	......	......	......
(22)	1 57 40 ,,	......	......	......	......	......	......
	1 58 0 ,,	24·394	62·5	......	5,780		
	1 58 30 ,,	......	......	24·52	......	......	......
(23)	1 58 40 ,,	......	......	......	......	......	......
	2 0 0 ,,	23·928	62·0	24·10	6,313		
	2 1 0 ,,	23·778	62·0	......	6,491		
	1.	2.	3.	4.	5.	6.	7.

(1) Birmingham in view?
(2) Wind N.W.; moving S.E.; gorgeous view.
(3) Light and shade magnificent.
(4) Balloon full; gas cloudy.
(5) Turned to descend.
(6) Opened valve.

(7) Most glorious view possible; cumuli far below, detached. Wolverhampton under us as a fine model.

(8) Plains of clouds in the distance.
(9) Opened valve.

(10) Rippling of edges of canal beautiful; calm; Black Country remarkable; alpine and dome-like clouds; bright on one side, dull on the other; detached cumuli; horizon apparently same height as the eye.

Balloon Ascents. Wolverhampton, August 18, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
......	......	45·7						
5·5	32·0							
6·5	29·2	43·0	......	......	......	......	30·±	
5·5	28·6	40·5						
......	......	38·5						
5·1	24·9							
4·5	24·8							
7·5	22·2							
6·0	28·6	41·8	......	......	......	......	22·0	25·0
7·0	29·9	......	......	......	......	......	24·0	
......	......	45·0						
6·7	32·0							
......	......	45·8						
6·7	33·1							
......	......	......	......	......	......	......	......	30·5
5·5	41·8	51·0	......	......	......	......	......	34·0
5·2	40·6	49·2	......	......	......	......	35·5	35·0
6·0	42·0	......	......	......	......	......	......	36·6
......	......	......	......	......	......	......	......	36·0
......	......	......	......	......	......	......	......	39·0
6·3	44·8							
6·5	44·6	53·8	......	......	......	......	......	37·5
6·5	45·7							
6·9	45·9	53·5						
......	......	......	......	......	......	......	......	43·5
6·5	47·8	......	......	......	......	......	46·0	
7·4	47·1							
7·5	47·0	......	......	......	......	......	47·8	47·2
5·0	49·6	56·0						
4·3	45·0	55·0						
3·7	44·7	......	......	......	......	......	......	40·0
3·2	44·5	......	......	......	......	......	42·0	
......	......	......	......	......	......	......	......	39·5
......	......	......	50·0	46·5	3·5	42·8	......	39·0
......	......	54·8						
......	......	......	52·2	46·8	5·4	41·3	......	39·0
8.	9.	10.	11.	12.	13.	14.	15.	16.

(11) The sun shining on shades of Dry and Wet Bulb; valve opened; beautiful resonant sound.
(12) Aspirator difficult to work. (13) Clouds very beautiful. (14) Warm to sense.
(15) About midway between Wolverhampton and large town, ? Walsall.
(16) Balloon collapsed. (17) Shouting below, thinking we are descending; a reservoir in sight. (18) Shaded the instruments.
(19) Protected the Dry Bulb from influence of sun; sand out; shouting.
(20) Beautiful prismatic colours round the balloon's shadow; passing along high road to Birmingham. (21) Bell heard in Birmingham very distinctly.
(22) Sand out. (23) Cumuli same height as car.

Table I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther.	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	2 1 30 p.m.	......	......	23·90	......	......	......
(2)	2 9 0 „	22·584	61·0	22·71	7,886	53·5	46·0
(3)	2 10 0 „	......	......	......	......	......	......
	2 10 30 „	22·182	62·1	......	8,571	51·0	45·5
	2 11 0 „	......	......	22·32	......	51·0	44·8
	2 11 40 „	21·882	62·0	......	8,771	......	......
	2 11 50 „	......	......	......	......	......	......
	2 12 0 „	......	......	......	......	......	......
	2 12 20 „	......	......	......	......	......	......
	2 13 0 „	21·882	62·1	......	8,771		
	2 13 40 „	......	......	21·95	......	......	......
(4)	2 13 50 „	......	......	......	......	53·2	44·5
	2 14 0 „	20·989	......	......	9,902	......	......
(5)	2 15 0 „	21·139	60·0	......	9,695	50·5	42·5
	2 15 30 „	......	......	......	......	......	......
(6)	2 17 0 „	20·239	61·5	20·50	10,864	45·5	37·1
	2 20 0 „	19·599	......	......	11,748	45·5	34·2
(7)	2 21 0 „	19·109	52·0	19·30	(12,364)	44·0	34·0
(8)	2 22 0 „	19·310	......	19·21	......	44·0	33·8
(9)	2 22 30 „	18·859	52·5	......	12,708		
	2 23 0 „	18·708	53·0	......	12,942	44·0	32·0
(10)	2 24 0 „	18·109	53·0	......	13,852	39·0	31·5
	2 25 0 „	......	......	......	......	......	......
(11)	2 25 20 „	17·614	......	17·85	14,434	......	......
(12)	2 29 0 „	16·410	48·0	16·50	16,339	37·5	27·2
(13)	2 31 0 „	......	......	......	......	......	......
(14)	2 32 0 „	15·926	......	......	17,157	39·5	31·5
(15)	2 32 10 „	......	......	......	......	......	......
	2 32 20 „	15·844	45·5	16·00	17,321	......	......
	2 32 30 „	......	......	......	......	37·1	29·5
	2 34 0 „	......	......	......	......	......	......
(16)	2 34 20 „	......	......	......	......	35·5	31·0
	2 35 0 „	15·600	......	15·50	18,039	......	......
	2 36 0 „	......	......	......	......	37·5	31·5
	2 36 10 „	......	......	......	......	......	......
	2 36 20 „	......	......	......	......	......	......
	2 36 30 „	15·026	47·5	......	18,560		
	2 36 40 „	......	......	15·02	......	......	......
	2 36 50 „	......	......	......	......	......	......
	2 37 50 „	......	......	......	......	36·1	31·5
(17)	2 38 10 „	14·868	52·5	......	19,000		
	2 38 30 „	......	......	14·92	19,230	......	......
	2 38 40 „	......	......	......	......	......	......
	2 38 50 „	......	......	......	......	39·0	31·2
(18)	2 39 0 „	14·617	......	......	19,461	[sun shining.	
	2 39 10 „	14·820	......	14·72	19,604		
	2 39 20 „	......	......	......	......	......	......
	1.	2.	3.	4.	5.	6.	7.

(1) Ozone 8; sand out. (2) Rippling of water on edges of canal very distinct.
(3) Near Lichfield. (4) Ozone: Moffat 2=1; Sch. =1; Moffat 1=8.
(5) Sand out. (6) Beautiful appearance still.
(7) Very extended view. (8) Balloon full and clear.
(9) Great mass of cloud to the E. (10) Large town to the right.
(11) Sea of clouds, very deep blue sky; snow-white appearances; balloon transparent:

Balloon Ascents. Wolverhampton, August 18, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
......	......	54·0	55·0	48·2	6·8	41·7		
7·5	38·6	50·5						
......	......	......	48·5	44·0	4·5	39·1	......	36·0
5·5	39·8							
6·2	38·4							
......	......	......	51·0	44·0	7·0	36·7	......	38·5
......	......	......	......	......	......	......	39·0	
......	......	......	......	......	......	......	......	39·0
......	......	......	......	......	......	......	39·5	
......	......	50·5						
8·7	34·9							
......	......	50·0						
8·0	34·1							
......	......	48·1						
8·4	27·4	......	42·1	37·1	5·0	31·0	......	29·5
11·3	21·2							
10·0	22·2	39·2	39·5	32·0	7·5	22·2	......	29·0
10·2	21·8	38·5						
12·0	17·9	38·0						
7·5	21·6	34·1						
......	......	......	39·5	32·5	7·0	23·4		
......	......	......	......	......	......	......	......	23·1
10·3	12·9	27·8						
......	......	......	36·5	21·5	15·0	− 0·7	......	6·0
8·0	21·1							
......	......	......	......	......	......	......	......	5·0
......	......	28·1						
7·6	18·8	......	35·0	21·0	14·0	− 1·4	[no dew.	
......	......	30·5	......	......	......	......	5·0	
4·5	24·0	......	......	......	......	......	......	3·5
......	......	......	31·5	21·0	10·5	− 5·4	......	3·0
6·0	23·2							
......	......	27·5	30·0	20·0	10·0	−11·5	......	0·0
......	......	28·0						
......	......	24·8	......	......	......	......	......	−2·0
......	......	25·5						
4·6	24·6							
......	......	......	......	......	......	......	......	−5·0
......	......	28·5						
7·8	21·0							
......	......	26·1						
8.	9.	10.	11.	12.	13.	14.	15.	16.

a few clouds below; cirrus still higher; gas getting foggy; cirrus still above at great height. (12) Sun shining on cases of Dry and Wet Bulb Thermometers.

(13) Ozone 1=10. (14) Ozone 2=6 (15) Ozone 3=7.

(16) Clap of thunder; no cloud in sight. (17) Aspirator troublesome to work.

(18) Sun shining on cases of Dry and Wet Bulb Thermometers; could not screen it; tried umbrella; failed.

Table I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	2 39 30 p.m.	14·600	......	14·50	20,000	......	......
	2 42 0 „	......	......	......	......	......	21·8
	2 42 10 „	14·118	......	......	20,359	......	......
(1)	2 45 0 „	......	......	......	......	......	......
	....	......	......	......	......	......	......
(2)	2 49 0 „	13·619	53·0	......	21,111		
	2 49 50 „	13.700	......	13·60	......	......	......
(3)	2 54 0 „						
	2 59 0 „	12·826	......	......	23,164	......	ice.
	2 59 10 „	12·714	......	......	23,215	......	......
	2 59 20 „	12·614	......	......	23,377	......	......
	2 59 40 „	12·932	......	......	22,762	......	......
	3 0 0 „	13·132	......	......	22,295		
(4)	3 2 0 „	......	......	13·00			
	3 2 20 „	13·132	43·0	......	22,295	......	......
	3 3 0 „	13·132	......	......	22,295		
(5)	....	......	......	......	......	......	......
	3 4 30 „	13·132	43·0	......	22,386	......	......
	....	12·932	......	13·20	22,607	......	......
(6)	3 5 30 „	......	......	......	......	......	......
	3 5 40 „	12·932	42·0	13·80	22,607		
(7)	3 6 0 „	12·835	......	......	23,023	[sun shining.	
	3 6 10 „	......	......	......	......	......	......
(8)	3 7 0 „	12·932	......	......	22,705	30·5	16·5
	3 12 30 „	12·932	......	......	22,705	38·2	28·5
	3 13 0 „	......	......	......	......	......	......
	3 13 15 „	13·627	......	......	21,977		
	3 13 20 „	......	......	......	......	......	......
	3 13 30 „	......	49·0	13·55	......	......	......
	....	13·577	......	......	22,008		
(9)	3 13 50 „						
(10)	3 18 30 „	13·447	......	13·5	22,107		
	3 19 20 „	......	......	13·55	......	[sun shining.	......
	3 19 30 „	......	......	......	......	34·0	29·1
	3 19 40 „	......	......	......	......	......	......
	3 19 50 „	......	......	......	......	......	......
(11)	3 25 0 „	13·649	46·0	13·72	21,330		
(12)	3 26 0 „	......	......	14·50			
	3 32 0 „	......	......	16·00			
	3 33 0 „	16·780	42·0	......	15,984		
	3 34 0 „	17·529	......	17·42	13,320	37·5	25·0
	3 36 0 „	18·629	42·0	18·65	12,453	42·0	28·8
	3 38 0 „	......	......	......	......	44·0	31·5
	1.	2.	3.	4.	5.	6.	7.

(1) Thunder heard below.
(2) A large town directly under us.
(3) Mr. Coxwell's pulse 90; Mr. Glaisher's 100, 107, and 110.
(4) Looked round; brandy necessary.
(5) Difficult to get dew; Mr. Coxwell helped me.
(6) Difficult to get dew.
(7) Hands and face blue.
(8) Aspirator difficult to work.
(9) Thunder loud.
(10) Mr. Coxwell looked over ballast, said we had better be content today and not go higher; I wished to go up.
(11) Unwell.
(12) Remarkable view; cirri far above; beautiful deep bluesky with cumuli far below. The earth and its fields very beautiful under us; here the earth not visible, a blue mist filling up the interstices between the cumuli; there the earth is perfectly clouded over by

Balloon Ascents. Wolverhampton, August 18, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
......	......	25·5						
......	......	......	......	......	......	......	......	− 8·5
......	......	25·1						
......	......	......	19·0	21·0	......	......	......	− 5·0
......	......	23·5						
......	......	25·4	22·1	22·1	......	......	......	−10·0
......	......	......	......	......	......	......	......	−12·0
......	......	24·2						
......	......	......	......	......	......	......	− 8·0	
......	......	24·0	......	......	......	......	......	−10·0
......	......	24·5	......	......	......	......	− 8·0	−10·0
......	......	24·8	......	......	......	......	......	−10·0
......	......	28·0	......	......	......	......	− 9·0	
......	......	28·1						
......	......	......	......	......	......	......	−10·0	
......	......	24·0						
14·0	−24·5	......	31·2	31·2	0·0	31·2	......	− 8·0
......	......	......	......	......	......	......	......	− 9·0
......	......	......	......	......	......	......	−10·0	
......	......	24·0						
......	......	......	......	......	......	......	......	−10·0
4·9	20·5							
......	......	25·0						
......	......	24·8						
12·5	9·8	32·8	......	......	......	......	......	12·5
13·2	12·6	38·0	......	......	......	......	......	14·0
12·5	5·4							
8.	9.	10.	11.	12.	13.	14.	15.	16.

large plains or seas of cumulostratus, causing all below to be cloudy for many hundreds of square miles, then many square miles without a cloud to obscure the sun's rays; other places with detached cumuli, whose upper surfaces were connected in vast plains of a hillocky appearance; earth obscured in places by a blue haze or mist; then again cumuli with blue mist between them; the earth cannot be seen owing to the blue mist filling up the spaces between the cumuli. In another place, beautiful shining cumuli, and then a sea of detached clouds which I cannot describe. Open to the N., S.E., and S.W., obscured to N.E.; saw 50° of horizon same height as the eye on looking over the top of the car. A beautiful cloud due N., the same we passed through on leaving Wolverhampton, and has followed us all the way; King of clouds.

TABLE I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	3 39 0 p.m.	20·020	45·0	20·05	10,624	44·2	30·5
	3 39 30 „	......	......	20·55			
	3 40 0 „	20·717	46·0	......	10,224	45·5	31·0
	3 41 0 „	......	......	21·50			
	3 41 30 „	21·617	......	......	8,764		
(1)	3 43 0 „	22·767	48·0	......	8,144		
	3 43 10 „	......	......	22·51	......	50·5	44·0
	3 43 30 „	22·737	......	......	7,438		
(2)	3 45 0 „	......	......	......	......	......	......
	3 46 0 „						
	3 46 10 „	23·880	......	......	6,050		
(3)	3 46 30 „	23·930	......	......	5,979		
(4)	3 47 0 „	......	......	......	......	......	......
(5)	3 48 0 „	23·980	......	......	5,922	53·5	43·5
	3 49 0 „	24·280	53·0	24·42	5,621	......	......
(6)	3 50 0 „	......	......	......	......	53·5	47·0
(7)	3 50 10 „	24·876	......	......	5,021		
(8)	3 50 20 „	25·083	......	......	4,821	52·1	48·0
(9)	3 51 0 „	25·364	......	......	4,521	51·5	49·2
	3 53 0 „	......	......	......	......	51·0	50·0
(10)	3 55 0 „						
(11)	3 58 0 „						
(12)	3 59 0 „						
(13)	4 4 0 „						
(14)	4 5 0 „	......	......	......	......	......	......
Crystal Palace, August 20, 1862.							
	6 5 0 p.m.	......	......	29·86	250	67·8	61·6
	6 26 0 „	......	......	29·86	250	66·2	60·5
(15)	6 27 0 „	......	......	29·85	250	66·0	60·5
	6 28 30 „	......	......	29·66	430	65·2	59·5
	6 29 0 „	......	......	29·62	450	64·6	59·0
	6 29 30 „	......	......	29·48	530	64·2	58·5
	6 29 40 „	......	......	29·40	602	64·1	58·2
	6 29 50 „	......	......	29·33	662	63·5	57·5
	6 30 0 „	......	......	29·28	707	63·2	57·5
	6 31 0 „	......	......	28·95	1,037	63·0	57·2
(16)	6 32 30 „	......	......	28·55	1,397	61·5	56·2
(17)	6 33 0 „	......	......	28·45	1,497	61·5	56·0
	6 34 0 „	......	......	28·00	1,912	58·5	54·2
(18)	6 35 0 „	......	......	27·75	2,160	57·5	53·1
(19)	6 35 30 „	......	......	27·65	2,257	56·2	53·0
	6 36 0 „	......	......	27·40	2,408	56·0	52·5
	6 37 0 „	......	......	......	......	55·2	52·1
	1.	2.	3.	4.	5.	6.	7.

(1) The image of balloon and car on cloud very distinct. (2) Entering cloud, lost sight of sun.
(3) In a cloud; fog; can see nothing. (4) Balloon image on cloud magnificent.
(5) In cloud again; again lost sun. (6) Still in cloud.
(7) Saw the earth. (8) Packed up some instruments. (9) Misty. (10) Out of mist.
(11) Descending slowly; one or two men breaking through hedges.

Balloon Ascents, Wolverhampton, August 18, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
13·7	14·4	40·7						
14·5	14·4							
6·5	36·7							
......	......	......	......	......	......	......	......	38·6
......	......	......	......	......	......	......	40·0	
10·0	33·6							
......	......	50·0						
6·5	40·5							
4·1	43·9							
2·3	44·8	51·5						
1·0	48·9							
......	......	67·0						
Crystal Palace, August 20, 1862.								
6·2	56·7	......	......	......	......	......	55·5	
5·7	55·9							
5·5	56·0							
5·7	54·8							
5·6	54·3							
5·7	53·7							
5·9	53·3							
6·0	52·5							
5·7	52·7							
5·8	52·3							
5·3	51·7							
5·5	51·3	......	......	......	......	......	52·1	
4·3	50·5							
4·4	49·1							
3·2	50·0	......	......	......	......	......	51·5	
3·5	49·2							
3·1	49·1							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(12) People approaching in different directions.
(13) Grapnel touched the earth. (14) Car touched the earth.
(15) Cheering from below. (16) Misty. (17) Over Palace Gardens.
(18) Counted ten carriages in train on Brighton Railway.
(19) Train on Beckenham line, twelve carriages, tank engine.

TABLE I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther.	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	6 37 10 p.m.	……	……	27·20	2,709	55·1	52·0
(1)	6 37 30 „	……	……	26·95	2,959	54·2	51·5
(2)	6 38 0 „	……	……	26·75	3,159	53·1	51·0
(3)	6 39 0 „	……	……	26·55	3,359	52·8	50·5
(4)	6 41 0 „	……	……	26·12	3,816	51·1	48·9
(5)	6 41 30 „	……	……	25·95	3,986	50·5	48·5
(6)	6 42 0 „	……	……	25·82	4,116	51·0	48·5
(7)	6 43 0 „	……	……	25·68	4,256	50·0	47·8
(8)	6 43 30 „	……	……	25·60	4,316	51·0	48·2
(9)	6 47 0 „	……	……	25·55	4,366	50·5	47·2
(10)	6 48 0 „	……	……	25·60	4,316	50·0	47·0
(11)	6 49 0 „	……	……	25·75	4,116	49·2	47·5
	6 49 30 „	……	……	25·80	4,055	50·5	48·5
(12)	6 50 0 „	……	……	26·05	3,893	51·5	48·2
	6 51 30 „	……	……	26·25	3,693	51·5	48·2
(13)	6 52 0 „	……	……	26·35	3,593	51·5	48·2
(14)	6 55 0 „	……	……	26·28	3,663	51·2	48·2
(15)	6 56 0 „	……	……	26·25	3,693	50·9	48·2
(16)	6 57 30 „	……	……	26·20	3,743	50·3	47·8
(17)	6 58 0 „	……	……	26·15	3,793	49·8	47·2
(18)	7 0 0 „	……	……	26·11	3,833	50·2	47·5
(19)	7 1 20 „	……	……	26·08	3,863	49·8	47·2
(20)	7 2 0 „	……	……	26·05	3,893	49·5	47·2
(21)	7 4 0 „	……	……	25·85	4,052	48·2	46·5
(22)	7 5 0 „	……	……	25·70	4,250	48·0	46·0
(23)	7 7 0 „	……	……	25·58	4,384	47·0	45·1
(24)	7 8 0 „	……	……	25·60	4,354	47·2	45·5
(25)	7 9 0 „	……	……	25·68	4,278	48·1	46·2
	7 10 0 „	……	……	26·50	3,405	48·2	46·5
(26)	7 12 0 „	……	……	26·20	3,621	49·8	46·5
(27)	7 13 0 „	……	……	26·45	3,468	51·0	48·2
(28)	7 15 0 „	……	……	27·50	2,398	53·5	51·0
(29)	7 16 0 „	……	……	27·70	2,198	54·2	51·5
	7 16 30 „	……	……	28·03	1,871	54·8	52·0
(30)	7 17 0 „	……	……	28·25	1,655	55·5	52·5
(31)	7 18 0 „	……	……	28·50	1,417	56·5	53·2
(32)	7 19 0 „	……	……	28·53	1,387	57·0	53·5
(33)	7 19 10 „	……	……	28·55	1,367	57·0	53·5
(34)	7 19 30 „	……	……	28·63	1,287	57·2	54·1
	7 20 0 „	……	……	28·64	1,277	57·5	54·2
	1.	2.	3.	4.	5.	6.	7.

(1) Over Crystal Palace. (2) Misty all round; detached scud beneath.
(3) Gas in balloon cloudy; saw people as specks; clouds beneath as scud.
(4) Over a wood near the Palace.
(5) Gas very cloudy, could see it coming out as smoke.
(6) Misty; still over wood. (7) Clouds far below, but not under us.
(8) In cloud; earth just visible. (9) Could not see people, but could see carriages; lost sight of earth at $6^{h}\ 47^{m}\ 10^{s}$; just see roads.
(10) Earth visible at $6^{h}\ 48^{m}\ 40^{s}$; earth seen plainly, except where obscured by scud.
(11) 28 vibrations of magnet $=40^{s}\cdot5$, not good. (12) Could see the river; London obscured.
(13) Sand out. (14) Misty; Crystal Palace seen.
(15) Could see railway junction; heard engine. (16) Crystal Palace scarcely visible.
(17) Clouds below; saw a light on the river. (18) Tolling of bells distinct.
(19) Mist more on one side than the other; great buzzing below; shouting.

Balloon Ascents. Crystal Palace, August 20, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	
3·1	49·0							
2·7	48·8	……	……	……	……	……	48·5	
2·1	48·9	……	……	……	……	……	48·0	
2·3	48·2							
2·2	46·6	……	……	……	……	……	44·2	
2·0	46·4							
2·5	45·9	……	……	……	……	……	44·2	
2·2	45·5							
2·8	45·3							
3·3	43·7							
3·0	43·8	……	……	……	……	……	44·5	
1·7	45·7	……	……	……	……	……	44·5	
2·0	46·4	……	……	……	……	……	45·0	
3·3	44·9	……	……	……	……	……	44·5	
3·3	44·9	……	……	……	……	……	44·5	
3·3	44·9	……	……	……	……	……	44·0	
3·0	45·1	……	……	……	……	……	44·0	
2·7	45·4	……	……	……	……	……	43·5	
2·5	45·2							
2·6	44·4	……	……	……	……	……	43·5	
2·7	44·7							
2·6	44·4							
2·3	44·7	……	……	……	……	……	43·0	
1·7	44·7							
2·0	43·8	……	……	……	……	……	43·0	
1·9	43·0	……	……	……	……	……	44·0	
1·7	43·7	……	……	……	……	……	43·5	
1·9	43·9							
1·7	44·7	……	……	……	……	……	42·5	
3·3	43·0							
2·8	45·3	……	……	……	……	……	45·0	
2·5	48·5							
2·7	48·9							
2·8	49·3	……	……	……	……	……	49·0	
3·0	49·6							
3·3	50·1							
3·5	50·3							
3·5	50·3	……	……	……	……	……	50·5	
3·1	51·3							
3·3	51·2							
8.	9.	10.	11.	12.	13.	14.	15	16.

(20) Kennington Oval in sight; getting over London.
(21) Heard noise of people; gas cloudy and issuing from neck like smoke.
(22) Misty still; $7^h\ 6^m\ 15^s$, cold to sense; $7^h\ 6^m\ 45^s$, earth invisible.
(23) Over London; great noise; $7^h\ 7^m\ 30^s$, listened and heard the hum of London plainly.
(24) Great hum of London; exactly over Kennington Oval; saw lights; $7^h\ 8^m\ 42^s$, St. Mark's church under us.
(25) Railway whistle heard.
(26) Lamps lighted along the roads.
(27) Bell tolling; two clumps of light visible.
(28) Milbank Penitentiary and Vauxhall Bridge in sight.
(29) Shouting heard.
(30) Lights on end of Vauxhall Bridge visible.
(31) Gas clear; see netting plainly.
(32) The upper and lower currents moving in different directions.
(33) Two gasometers under us near Kennington.
(34) Becalmed; visible from the earth.

TABLE I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	7 20 30 p.m.	......	......	28.62	1,297	57.5	54.2
(1)	7 22 0 ”	......	......	28.33	1,587	57.8	54.2
	7 23 0 ”	......	......	28.25	1,667	57.2	54.2
(2)	7 24 0 ”	......	......	28.01	1,907	56.8	53.5
(3)	7 25 0 ”	......	......	27.85	2,067	56.8	53.5
	7 25 20 ”	......	......	27.75	2,167	56.2	53.1
	7 26 0 ”	......	......	27.70	2,217	56.5	53.2
(4)	7 26 30 ”	......	......	27.70	2,217	56.5	53.5
(5)	7 28 0 ”	......	......	27.78	2,297	56.8	53.3
(6)	7 29 30 ”	......	......	27.70	2,217	55.9	52.9
(7)	7 30 0 ”	......	......	27.58	2,417	55.5	52.8
(8)	7 32 0 ”	......	......	......	......	55.2	52.2
(9)	7 33 0 ”	......	......	27.18	2,723	54.2	51.5
	7 34 0 ”	......	......	27.18	2,723	54.8	52.0
(10)	7 35 0 ”	......	......	27.22	2,683	55.2	52.0
	7 36 0 ”	......	......	27.30	2,603	54.8	51.6
(11)	7 37 0 ”	......	......	......	......	54.2	51.5
(12)	7 40 0 ”	......	......	27.03	2,873	53.5	49.8
(13)	7 41 0 ”	......	......	26.80	3,003	53.0	49.5
(14)	7 42 0 ”	......	......	26.10	3,703	51.2	48.0
(15)	7 47 0 ”	......	......	24.82	5,194	45.0	43.5
	7 48 0 ”	......	......	24.90	5,106	45.0	43.5
(16)	7 49 0 ”	......	......	24.18	5,900	43.0	
(17)	7 50 0 ”	......	......	24.	......	43.0	
	7 52 0 ”	......	......	24.88	5,200	43.3	
(18)	7 55 0 ”	......	......	24.88	5,200	44.2	
(19)	7 56 0 ”	......	......	24.92	5,160	44.2	
	7 57 0 ”	......	......	25.00	5,080		
(20)	8 5 0 ”	......	......	23.	......	55.0	
	1.	2.	3.	4.	5.	6.	7.

(1) One-half of Kennington Oval is lighted; gas coming out from neck clear.
(2) Getting too dark to see the dew on the black bulb of the Hygrometer.
(3) Gas clear; great noise below; no wind; see earth; foggy below.
(4) Moving slowly near water. (5) Heard Victoria bell.
(6) Over Vauxhall Bridge; sand out.
(7) Saw Regent Street and Serpentine.
(8) Loud noise below; see the river for miles.
(9) Railway whistle; could distinguish the squares below; looked well lighted up.
(10) Going over Westminster; over Wellington Barracks.
(11) Gas cloudy; saw two bridges together over the river.
(12) Saw the Strand and Crescent lighted up brilliantly.
(13) London looks beautiful; Houses of Parliament, Charing Cross, and Piccadilly distinct; dark below.
(14) Heard church clock strike.
(15) In cloud; London out of sight.
(16) Blue sky; clouds below a rich red; packed up Wet Bulb.
(17) In cloud; too dark to read instruments; $7^h\ 51^m$, counted ballast bags, we have four;

Balloon Ascents. Crystal Palace, August 20, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
3·3	51·2							
3·6	51·0							
3·0	51·4							
3·3	50·5	......	......	......	......	......	49·0	
3·3	50·5							
3·1	50·2							
3·3	50·1							
3·0	50·7							
3·5	50·1							
3·0	50·1							
2·7	50·2							
3·0	51·3							
2·7	48·8							
2·8	49·3							
3·2	47·9							
3·2	48·5							
2·7	48·8							
3·7	46·1							
3·5	46·0							
3·2	44·7							
1·5	41·8							
1·5	41·8							
8.	9.	10.	11.	12.	13.	14.	15.	16.

7^h 52^m, gas cloudy; above clouds, beautiful view; London out of sight; 7^h 54^m, gas cloudy; can scarcely see to write.

(18) The setting sun tinged the clouds with red.

(19) In cloud; just see above; earth pitchy dark.

(20) Agitated dry-bulb thermometer over side of the car. The hum of London was distinct, and then gradually died away. The balloon, after a time, was allowed to descend below the clouds; the appearance of London, as now viewed through mist, was that of an immense conflagration; the lights were not, as before, innumerable and distinct points, but large in volume, united, and of wonderful extent; this appearance continued till we again ascended above the clouds, where it was much lighter, but not sufficiently so to enable the instruments to be read; and thus we journeyed till again descending below the clouds, we heard the lowing of cattle, indicating that we were some distance from London; the balloon was allowed to descend very slowly, for it was quite dark. Mr. Coxwell had sand ready to discharge on the instant, which he did on nearing trees, hedges, &c., and thus we passed over them and dropped gently to the ground, in the centre of a field near Hendon, a little before 10 o'clock. The grapnel was not used, as Mr. Coxwell was fearful of hurting some one, or otherwise doing injury.

TABLE I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	4 30 0 a.m.	......	......	29.63	320	60.8	59.5
	4 31 0 „	......	......	29.59	358	60.0	58.5
	4 33 0 „	......	......	29.58	367	58.9	58.0
(1)	4 35 0 „	......	......	29.45	490	59.2	59.0
	4 36 0 „	......	......	29.20	728	59.0	59.0
	4 38 0 „	......	......	......	......	58.2	56.5
	4 39 0 „	......	......	28.78	1,130	57.8	54.8
(2)	4 40 0 „	......	......	28.70	1,210	57.5	54.2
(3)	4 41 0 „	......	......	28.62	1,286	57.2	53.8
(4)	4 42 0 „	......	......	28.58	1,326	56.8	53.8
(5)	4 44 0 „	......	......	28.18	1,706	55.5	53.5
(6)	4 45 0 „	......	......	27.90	2,000	55.0	53.0
(7)	4 49 0 „	......	......	26.95	2,930	52.2	49.8
(8)	4 51 0 „	......	......	26.40	3,510	49.8	47.2
	4 52 0 „	......	......	25.95	3,951	47.0	44.2
	4 53 0 „	......	......	25.78	4,138	46.5	43.8
(9)	4 55 0 „	......	......	25.05	4,927	43.8	42.8
	4 55 30 „	......	......	24.72	5,260	43.2	42.2
(10)	4 56 0 „	......	......	......	......	42.0	41.2
	4 57 0 „	......	......	24.45	5,557	40.2	40.0
(11)	4 57 30 „	......	......	24.05	5,989	39.7	39.7
(12)	4 58 0 „						
(13)	4 58 30 „	......	......	23.70	6,367		
(14)	5 0 0 „	......	......	23.58	6,510	38.5	37.5
(15)	5 1 0 „						
(16)	5 1 20 „						
(17)	5 3 0 „	......	......	23.75	6,336	40.7	37.0
(18)	5 4 0 „	......	......	23.68	6,413	41.5	37.2
(19)	5 5 0 „	......	......	23.20	6,967	40.5	37.0
	5 7 0 „	......	......	23.15	7,027	40.5	36.5
(20)	5 8 0 „	......	......	23.10	7,087	41.0	35.8
	5 10 0 „	......	......	22.48	7,810	37.5	32.5
(21)	5 11 0 „	......	......	22.10	8,281	37.2	32.0
	5 12 0 „	......	......	22.00	8,406	35.0	30.5
	5 14 0 „	......	......	21.65	8,841	35.2	29.8
	5 15 0 „	......	......	21.40	9,150	34.8	29.2
	5 15 30 „	......	......	21.10	9,525	33.0	28.2
	5 16 0 „	......	......	20.65	10,085	32.8	26.0
	5 17 0 „	......	......	20.45	10,335	31.9	26.0
(22)	5 18 0 „	......	......	20.30	10,472	31.0	26.5
(23)	5 20 0 „	......	......	19.70	11,222	29.8	(31)
	1.	2.	3.	4.	5.	6.	7.

(1) Line of light to the east. (2) Thick mist.

(3) Clouds broken in the east; beautiful lines of light; gold and silver tints.

(4) Balloon spirating; heard voices calling from below.

(5) Clouds beautiful; could see the earth in the distance.

(6) Very misty; blocks of clouds above; cold to sense; voices calling from below: Daniell's Hygrometer was broken the night before; I had attempted to mend it, but it would not work.

(7) Scud below creeping over the earth; cumuli on same level in the distance; black clouds above; over Mr. Wolley's farm. (8) Heard railway train.

(9) A great many ponds of water in sight; entered the clouds a few seconds afterwards.

(10) Lost sight of earth.

(11) Great masses of alpine cloud; beautiful cumulus cloud.

alloon Ascents. Hendon, August 21, 1862.

ometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
1·3	58·4							
1·5	57·2							
0·9	57·2							
0·2	58·9							
0·0	59·0							
1·7	55·0							
3·0	52·2							
3·3	51·2							
3·4	50·6							
3·0	51·0							
2·0	51·2							
2·0	51·1							
2·4	47·4							
2·6	44·4							
2·8	41·0							
2·7	40·7							
1·0	41·5							
1·0	41·0							
0·8	40·2							
0·2	39·8							
0·0	39·7							
1·0	36·0							
3·7	32·3							
4·3	31·8							
3·5	32·5							
4·0	30·9							
5·2	29·2							
5·0	25·5							
5·2	24·7							
4·5	23·3							
5·4	21·2							
5·6	20·2							
4·8	18·6							
6·8	12·4							
5·9	10·1							
4·5	14·3							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(12) In cloud, surrounded by white mist. (13) Sensibly lighter; a light wind.
(14) Valley of cloud; in a basin; on reaching its limit saw the sun rising.
(15) Like a lake under the sun; immense ocean of cloud; magnificent view.
(16) Under the sun a lake; mountains of cloud to the left; fine cloudscape.
(17) Lost sight of sun; earth visible underneath; misty.
(18) Deep ravines and shaded parts in clouds; sun again rising in the same magnificent way; silver and golden tints.
(19) Lake and mountain scenery; clouds near us sweeping boldly away.
(20) Moon seen. (21) Cold to the sense; gas clear.
(22) Applied water to Wet Bulb.
(23) Mr. Glaisher's pulse 88.

TABLE I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet The-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	5 21 0 a.m.	......	......	19·45	11,616	27·8	
(2)	5 22 0 ”	......	......	19·09	12,254	25·5	(31)
(3)	5 23 0 ”	......	......	18·90	12,421	23·2	
(4)	5 24 0 ”	......	......	18·90	12,421	23·3	(31)
	5 24 30 ”	......	......	18·80	12,571	23·0	
	5 25 0 ”	......	......	18·70	12,691	23·3	
	5 26 0 ”	......	......	18·60	12,831	23·5	(29·5)
	5 27 0 ”	......	......	18·42	13,080	24·0	(29·0)
	5 29 0 ”	......	......	18·20	13,381	24·0	19·5
	5 29 30 ”	......	......	18·15	13,456	23·5	18·5
	5 30 30 ”	......	......	18·00	13,665	25·0	20·2
	5 31 0 ”	......	......	17·90	13,680	22·2	16·2
	5 32 0 ”	......	......	17·88	13,685	21·5	16·0
	5 32 10 ”	......	......	......	......	21·0	14·5
	5 32 30 ”	......	......	17·82	13,799	19·5	13·8
	5 34 0 ”	......	......	17·78	13,875	19·5	13·2
(5)	5 34 30 ”	......	......	17·78	13,875	19·3	12·2
	5 35 0 ”	......	......	17·70	14,027	19·5	12·2
(6)	5 36 0 ”	......	......	17·72	13,989	19·9	13·0
	5 36 30 ”	......	......	17·71	14,008	20·0	13·5
	5 37 0 ”	......	......	17·70	14,027	20·5	14·0
	5 38 0 ”	......	......	17·65	14,121	21·5	14·9
	5 38 30 ”	......	......	17·62	14,178	22·5	16·5
	5 40 0 ”	......	......	17·68	14,064	24·0	18·0
	5 42 0 ”	......	......	17·68	14,068	24·8	20·0
(7)	5 43 0 ”	......	......	17·62	14,178	24·8	20·5
	5 44 0 ”	......	......	17·62	14,178	25·2	20·5
	5 44 30 ”	......	......	17·62	14,178	26·5	19·5
	5 45 0 ”	......	......	17·58	14,254	26·5	19·7
	5 45 45 ”	......	......	17·58	14,254	26·3	19·9
	5 46 0 ”	......	......	17·58	14,254	27·2	20·0
	5 46 15 ”	......	......	17·58	14,254	27·2	20·0
	5 47 0 ”	......	......	17·56	14,355	27·6	20·0
(8)	5 48 0 ”	......	......	17·57	14,273	26·0	20·5
(9)	5 48 30 ”	......	......	17·58	14,254	25·5	
	5 50 0 ”	......	......	17·57	14,273	25·5	19·0
	5 50 45 ”	......	......	17·58	14,254	25·1	18·9
(10)	5 51 0 ”	......	......	17·56	14,318	25·2	18·1
	5 52 0 ”	......	......	17·60	14,258	24·1	18·8
(11)	5 55 0 ”	......	......	17·62	14,228	23·8	17·5
	5 56 0 ”	......	......	17·62	14,228	23·8	17·8
	5 56 30 ”	......	......	17·62	14,228	23·0	17·5
(12)	5 57 0 ”	......	......	17·62	14,228	23·1	17·1
	5 57 30 ”	......	......	17·61	14,243	22·5	17·1
	5 58 0 ”	......	......	17·60	14,258	23·0	16·5
(13)	5 58 30 ”	......	......	17·62	14,228	23·4	16·5
	5 59 30 ”	......	......	17·62	14,228	23·4	16·4
(14)	6 0 0 ”	......	......	17·63	14,213	23·5	16·5
	1.	2.	3.	4.	5.	6.	7.

(1) Master Glaisher's pulse 89.
(2) Captain Percival's pulse 88.
(3) Mr. Coxwell's pulse 90.
(4) Mr. Ingelow's pulse 100.
(5) Magnificent peaks of cloud in distance, rising from a base like seas of cotton;
transparent.
(6) Network looks beautiful, perfect symmet
of form. Feet very cold; our boots covered with ice.

Balloon Ascents. Hendon, August 21, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
4·5	− 7·1							
5·0	9·8							
4·8	6·3							
6·0	23·4							
5·5	20·0							
6·5	30·2							
5·7	27·4							
6·3	32·4							
7·1	39·2							
7·3	40·6							
6·9	36·2							
6·5	22·6							
6·5	21·5							
6·6	29·5							
6·0	22·1							
6·0	17·5							
4·8	6·5							
4·3	3·2							
4·7	4·4							
7·0	14·4							
6·8	13·2							
6·4	12·4							
7·2	12·4							
7·2	12·4							
7·6	13·1							
5·5	7·4							
6·5	15·4							
6·2	15·3							
7·1	21·8							
5·3	12·5							
6·3	19·7							
6·0	17·7							
5·5	17·0							
6·0	20·5							
5·4	17·6							
6·5	24·3							
6·9	25·6							
7·0	27·5							
7·0	−27·4							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(7) Ice on Wet Bulb and connecting-thread. (8) Sea of clouds below.
(9) Fine echo from balloon. (10) Sun obscured by thin strati.
(11) Sea of clouds all round. (12) Stratus same height; cirrus above. (13) Valve twice opened.
(14) Beautiful sea of cloud everywhere; dropped paper, visible two minutes.

TABLE I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	6 1 0 a.m.	......	......	17·70	14,108	24·2	16·5
	6 2 0 „	......	......	17·90	13,802	24·5	16·5
	6 2 30 „	......	......	17·95	13,715	24·2	16·8
	6 3 0 „	......	......	18·10	13,484	23·8	16·5
(1)	6 4 0 „	......	......	18·11	13,479	24·2	16·5
(2)	6 4 30 „	......	......	18·15	13,419	24·2	16·7
	6 5 30 „	......	......	18·23	13,299	25·2	18·2
	6 6 0 „	......	......	18·30	13,194	25·2	19·2
	6 6 15 „	......	......	18·35	13,119	25·2	18·9
	6 8 0 „	......	......	......	......	24·5	18·8
(3)	6 12 0 „	......	......	19·07	12,174	30·0	24·0
	6 12 20 „	......	......	19·11	12,123	29·8	23·0
	6 13 0 „	......	......	19·15	12,070	27·8	22·0
(4)	6 13 30 „	......	......	19·28	11,901	27·5	21·2
	6 14 0 „	......	......	19·30	11,875	27·8	21·3
	6 14 30 „	......	......	19·30	11,875	27·5	21·5
	6 15 0 „	......	......	19·30	11,875	27·8	21·5
	6 16 0 „	......	......	19·65	11,420	31·5	23·8
	6 17 0 „	......	......	19·80	11,225	32·0	25·0
	6 18 0 „	......	......	20·05	10,871	33·8	26·0
	6 18 15 „	......	......	20·20	10,688	34·5	27·1
	6 18 30 „	......	......	20·30	10,566	36·5	28·2
	6 19 0 „	......	......	20·80	9,936	37·0	29·2
(5)	6 20 0 „	......	......	21·00	9,650	37·0	29·5
	6 22 0 „	......	......	21·70	8,810	41·5	31·0
(6)	6 23 30 „	......	......	22·20	8,196	43·5	32·2
(7)	6 24 0 „	......	......	22·33	8,040	43·0	33·0
(8)	6 25 0 „	......	......	22·65	7,655	42·8	32·5
	6 25 30 „	......	......	22·72	7,573	43·5	33·0
(9)	6 27 0 „	......	......	22·95	7,293	44·5	33·0
(10)	6 27 30 „	......	......	23·08	7,141	44·2	34·0
	6 28 0 „	......	......	23·12	7,094	43·0	35·2
(11)	6 28 30 „	......	......	23·11	7,106	42·8	36·0
(12)	6 29 0 „	......	......	23·20	7,001	43·0	37·2
(13)	6 30 0 „	......	......	23·30	6,884	43·0	38·5
(14)	6 31 0 „	......	......	23·28	6,907	42·0	40·5
(15)	6 31 30 „	......	......	23·40	6,767	42·5	41·0
	6 32 0 „	......	......	23·50	6,650	42·0	40·5
	6 32 15 „	......	......	23·60	6,533	42·0	40·5
(16)	6 33 0 „	......	......	24·00	6,058	41·5	39·8
	6 33 30 „	......	......	24·22	5,819	41·8	39·8
	6 33 40 „	......	......	24·50	5,515	41·5	39·8
	6 34 0 „	......	......	24·70	5,298	42·2	40·5
(17)	6 35 0 „	......	......	24·80	5,189	43·5	41·0
	6 36 0 „	......	......	24·90	5,080	44·2	41·1
	6 36 30 „	......	......	24·92	5,058	43·8	41·2
	6 37 0 „	......	......	25·10	4,851	45·2	41·5
	1.	2.	3.	4.	5.	6.	7.

(1) Valve opened.
(2) Valve opened.
(3) Dropped large piece of paper with our names written on it.
(4) Train heard.
(5) Could hear the watch tick when the ear was above it, but not when below.
(6) Gun heard.
(7) Balloon reflection on cloud, surrounded by prismatic colours.
(8) Dog barking; railway train heard.

Balloon Ascents. Hendon, August 21, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
7·7	−29·0							
8·0	29·4							
7·4	17·0							
7·3	26·7							
7·7	19·0							
7·5	27·7							
7·0	17·3							
6·0	13·9							
6·3	15·9							
5·7	−13·8							
6·0	+ 5·1							
6·8	+ 1·6							
5·8	+ 1·8							
6·3	− 6·8							
6·5	− 5·4							
6·0	− 5·4							
6·3	− 4·4							
7·7	− 5·5							
7·0	+ 8·8							
7·8	17·3							
7·4	14·7							
8·3	16·0							
7·8	18·1							
7·5	18·7							
10·5	18·0							
11·3	18·7							
10·0	21·0							
10·3	20·1							
10·5	20·5							
11·5	19·6							
10·2	22·0							
7·8	25·8							
6·8	27·8							
5·8	30·2							
4·5	33·1							
1·5	38·7							
1·5	39·2							
1·5	38·7							
1·5	38·7							
1·7	37·7							
2·0	37·3							
1·7	37·7							
1·7	37·9							
2·5	38·0							
3·1	37·5							
2·6	39·2							
3·7	+37·2							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(9) Clouds approached.
(10) Lost sight of sun.
(11) In mist.
(12) Just entering the clouds.
(13) Top of cloud.
(14) Valve opened.
(15) Fog; mist.
(16) Earth visible.

(17) Passed through cloud about 2000 feet in thickness, and found the country without a ray of sun, misty and dark.

TABLE I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	6 37 30 a.m.	......	......	25·20	4,745	45·0	42·2
	6 37 45 „	......	......	25·30	4,639	45·0	42·2
	6 38 0 „	......	......	25·60	4,320	46·0	43·2
(1)	6 38 30 „	......	......	25·92	3,980	46·8	43·8
	6 39 0 „	......	......	26·15	3,751	47·8	44·8
	6 40 0 „	......	......	26·40	3,502	48·2	45·1
(2)	6 41 0 „	......	......	26·60	3,300	49·5	47·2
	6 42 0 „	......	......	26·80	3,186	50·0	47·8
	6 42 15 „	......	......	27·00	2,872	51·0	48·2
	6 43 0 „	......	......	27·20	2,673	51·5	48·2
	6 44 0 „	......	......	27·70	2,177	53·5	50·1
	6 45 0 „	......	......	27·98	1,898	54·5	51·2
	6 45 30 „	......	......	28·20	1,684	55·5	52·0
	6 46 0 „	......	......	28·40	1,489	56·0	52·5
(3)	7 10 0 „	......	......	29·42	513	61·8	56·0
Crystal Palace, September 1, 1862.							
(4)	4 5 0 p.m.	......	......	......	......	63·0	59·9
(5)	4 40 0 „	29·80	......	29·78	250	63·8	59·8
(6)	4 45 0 „	......	......	29·78	250	65·0	59·8
	4 52 0 „	......	......	......	270	64·0	59·8
(7)	4 53 0 „	29·45	......	29·65	320	63·0	57·0
	4 53 20 „	29·15	......	29·20	720	61·1	56·5
	4 53 40 „	28·80	......	28·90	996	59·2	54·5
	4 54 0 „	28·52	......	28·55	1,332	57·2	54·1
	4 54 30 „	28·10	......	28·00	1,868	55·2	52·5
(8)	4 55 0 „	27·80	......	27·65	2,214	54·2	51·0
(9)	4 56 4 „						
(10)	4 57 0 „	27·30	......	27·21	2,654	52·2	49·5
	4 58 30 „	26·99	......	26·92	2,940	51·5	47·8
(11)	4 59 0 „	26·90	......	26·91	2,950	50·5	47·2
(12)	5 1 0 „	26·80	......	26·78	3,080	50·0	46·5
(13)	5 1 30 „	26·70	......	26·69	3,170	50·0	46·5
	5 2 15 „						
	5 3 0 „	26·65	......	26·61	3,257	49·5	46·5
(14)	5 4 0 „	26·60	......	26·60	3,268	49·2	46·0
(15)	5 5 30 „	26·45	......	26·46	3,408	49·2	
(16)	5 5 40 „	26·45	......	26·46	3,408	49·2	44·8
	5 6 30 „	26·40	......	26·41	3,458	49·5	44·8
(17)	5 7 0 „						
(18)	5 8 0 „	26·40	......	26·41	3,458	49·5	44·2
	1.	2.	3.	4.	5.	6.	7.

(1) Biggleswade under us. (2) Shouting heard; people not visible.

(3) On the ground, four miles from Biggleswade. In this ascent the Aneroid Barometer was read by Mr. Ingelow.

(4) Clouds, stratus, about a mile high.

(5) Blue sky near horizon, which was moderately clear.

(6) Wind E.N.E. (7) 4h 53m 40s, over south tower of the Palace.

(8) The whole course of the Thames to Richmond is in sight; gas cloudy.

(9) Mouth of the Thames and its course up to and beyond Richmond in sight.

Balloon Ascents. Hendon, August 21, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
2·8	38·9							
2·8	38·9							
2·8	40·0							
3·0	40·8							
3·0	41·6							
3·1	42·6							
2·3	44·7							
2·2	45·5							
2·8	45·3							
3·3	44·8							
3·4	46·7							
3·3	48·0							
3·5	48·6							
3·5	47·8							
5·8	51·1							
Crystal Palace, September 1, 1862.								
3·1	57·3							
4·0	56·5	......	......	......	......	......	52·0	
5·2	55·5							
4·2	56·3							
6·0	51·9	......	......	......	......	......	52·0	
4·6	52·5							
4·7	50·3							
3·1	51·2							
2·7	47·8							
3·2	48·1	......	......	......	......	......	45·1	
2·7	46·7							
3·7	44·0	......	......	......	......	......	47·8	
3·3	43·7							
3·5	42·8	......	......	......	......	......	43·0	
3·5	42·8							
3·0	43·3	......	......	......	......	......	43·5	
3·2	42·6							
4·4	40·1							
4·7	39·8							
5·3	38·5	......	......	......	......	......	38·5	
8.	9.	10.	11.	12.	13.	14.	15.	16.

(10) Palace like a mist; heard railway whistle, and close over Norwood.
(11) Railway whistle heard; two trains together.
(12) Rays of sun lighting up Gravesend.
(13) Gas very cloudy; rays of sun perpendicularly downwards; over Mitcham Common.
(14) Over Mitcham Common; people not visible.
(15) Carriages visible; wind E.N.E.
(16) Cumulus in horizon; apparently at a lower elevation.
(17) Palace beautiful. (18) Over water.

Table I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 1.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	5 9 0 p.m.	26·50	……	26·50	3,368	49·8	44·2
	5 10 0 „	26·50	……	26·55	3,318	50·0	44·8
	5 10 30 „	26·48	……	26·51	3,358	50·0	44·8
(2)	5 11 30 „	26·30	……	26·31	3,560	50·0	44·8
(3)	5 13 0 „	26·20	……	26·19	3,680	48·8	43·5
(4)	5 13 20 „						
(5)	5 15 0 „	26·20	……	26·19	3,680	49·2	44·1
(6)	5 15 40 „						
(7)	5 16 0 „	26·25	……	26·25	3,620	49·2	44·0
(8)	5 17 0 „	26·29	……	26·29	3,580	49·2	44·1
(9)	5 17 40 „						
(10)	5 19 0 „	26·28	……	26·28	3,590	48·8	43·1
(11)	5 20 0 „	26·29	……	26·29	3,583	47·8	42·8
(12)	5 23 0 „	25·95	……	25·95	3,937	47·2	43·0
	5 23 30 „	25·94	……	25·91	3,977	47·2	42·1
	5 24 0 „	25·90	……	25·90	3,987	47·0	42·1
(13)	5 25 0 „	25·90	……	25·90	3,987	47·2	42·5
(14)	5 26 0 „	26·09	……	26·05	3,837	48·1	42·5
	5 26 30 „	26·15	……	26·15	3,737	48·2	43·5
	5 27 0 „	26·20	……	26·20	3,687	48·5	43·5
(15)	5 28 0 „	26·10	……	26·10	3,787	47·8	42·5
	5 29 0 „	25·95	……	26·00	3,887	47·2	42·1
(16)	5 30 0 „	25·88	……	25·88	4,000	47·2	42·5
(17)	5 31 0 „	25·75	……	25·79	4,090	47·2	42·1
(18)	5 32 0 „	25·65	……	25·70	4,180	46·2	41·5
	5 33 0 „	25·69	……	25·69	4,190	46·2	41·5
	5 35 0 „	25·69	……	25·69	4,190	46·1	41·5
(19)	5 36 0 „						
(20)	5 37 0 „	25·96	……	25·98	3,900	47·2	42·8
(21)	5 37 30 „	26·20	……	26·19	3,690	47·2	42·5
	5 40 0 „	26·55	……	26·50	3,362	47·5	43·2
(22)	5 41 0 „						
	5 42 0 „	26·82	……	26·82	3,040	48·5	44·2
	5 43 0 „	26·95	……	26·95	2,910	49·2	45·5
	5 44 0 „	26·95	……	26·95	2,910	49·8	46·1
(23)	5 45 0 „	26·90	……	26·88	2,970	49·2	46·1
(24)	5 46 0 „						
(25)	5 47 0 „						
	1.	2.	3.	4.	5.	6.	7.

(1) Wind changed to E. (2) Wind E.S.E.

(3) Over corn-fields. (4) Three trains in sight; gas cloudy.

(5) Gun heard. (6) Gas escaping from balloon at safety-valve very fast.

(7) Apparently on a level with cumuli in distance; train; sun shining in distance.

(8) Train seen; old Battersea Bridge near; South-Western Railway under us; near to Maldon; moving in the direction of Richmond Park; newly made reservoir (of red bricks) under us; dog barking; wind E.N.E.

(9) Over embankment of South-Western Railway; Thames very clear.

(10) Crystal Palace visible from the ring.

(11) Seemed to have changed direction; could see the four black lines of railway.

(12) The islands in the Thames near Mortlake very clear.

(13) Supposed nearly over Hampton Court.

(14) Gas very cloudy. (15) Shouting below.

(16) Gas coming out of valve fast like smoke; higher than all clouds near us; could see the mouth of the Thames very plainly; some said they could see the sea.

Balloon Ascents. Crystal Palace, September 1, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
5·6	38·2							
5·2	39·3							
5·2	39·3							
5·2	39·3							
5·3	37·8	......	......	......	......	......	38·5	
5·1	38·6							
5·2	38·4	......	......	......	......	......	38·4	
5·1	38·6							
5·7	37·0	......	......	......	......	......	35·0	
5·0	37·3	......	......	......	......	......	33·1	
4·2	38·3							
5·1	36·4							
4·9	36·6	......	......	......	......	......	35·0	
4·7	37·2							
5·6	36·4							
4·7	38·4							
5·0	38·0							
5·3	36·6	......	......	......	......	......	33·0	
5·1	36·4							
4·7	36·3							
5·1	36·4	......	......	......	......	......	35·5	
4·7	36·1							
4·7	36·1	......	......	......	......	......	34·0	
4·6	36·0							
4·4	37·9							
4·7	37·2	......	......	......	......	......	37·5	
4·3	38·4	......	......	......	......	......	38·0	
4·3	39·6							
3·7	41·6							
3·7	42·2	......	......	......	......	......	41·5	
3·1	42·8							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(17) Clouds follow the course of the Thames from its mouth up to the higher parts of the river, seemingly following the whole course of the river, and confined to it throughout; quite clear where we are; clouds far below, moving apparently at right angles to us.

(18) Thames Ditton under us.

(19) Fast train on South-Western Railway; upper current W.?; clouds meeting us, moving at right angles to our motion; clouds very low.

(20) Clouds passing quickly below us; can scarcely see the earth on one side; clouds still follow the course of the river.

(21) Can see the earth at intervals through the clouds.

(22) Clouds meeting us of three different degrees of white—the top bluish white, the middle the pure white of the cumulus, the lower blackish white, and from which rain was falling upon the earth.

(23) Train with 29 carriages seen; gas beautifully clear; netting seen through it, and balloon apparently empty.

(24) Can see carts; hear people shouting. (25) Saw a black dog, and heard him bark.

TABLE I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 1.	Height above sea-level.	Dry and Wet Ther.	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	5 48 0 p.m.	26·68	......	26·68	3,170	48·2	44·5
	5 50 0 ,,	26·99	......	26·90	2,950	49·2	44·5
	5 52 0 ,,	......	......	27·49	2,356	50·0	46·5
	5 53 0 ,,	......	......	27·40	2,446	50·5	47·2
	5 53 30 ,,	......	......	27·40	2,446	50·5	47·8
	5 54 0 ,,	......	......	27·44	2,406	50·0	48·0
(1)	5 55 0 ,,						
	5 56 0 ,,	27·60	......	27·55	2,290	51·0	49·2
(2)	5 57 0 ,,	27·65	......	27·65	2,190	51·2	49·2
	5 57 30 ,,	......	......	......	......	52·0	50·5
(3)	5 58 0 ,,	......	......	27·95	1,890	52·0	50·5
	5 58 10 ,,	......	......	28·05	1,790	52·5	50·0
	5 58 30 ,,	28·12	......	......	......	53·2	50·5
	5 59 0 ,,	......	......	28·22	1,620	53·2	50·5
	5 59 30 ,,	......	......	28·30	1,540	53·8	51·0
(4)	6 0 0 ,,	......	......	28·45	1,417	54·0	51·0
(5)	6 0 20 ,,						
	6 0 30 ,,	......	......	28·52	1,347	54·2	51·2
(6)	6 1 0 ,,	......	......	28·50	1,367		
(7)	6 2 0 ,,	......	......	28·30	1,567	54·0	51·7
	6 3 0 ,,	......	......	28·19	1,677	54·0	51·5
	6 3 30 ,,	......	......	28·05	1,817	54·0	51·5
	6 4 0 ,,	......	......	27·81	2,057	54·2	51·5
(8)	6 5 0 ,,	......	......	27·75	3,117	53·5	51·5
	6 5 30 ,,	......	......	27·75	3,117	53·5	51·5
(9)	6 6 0 ,,	......	......	27·75	3,117	54·2	51·5
(10)	6 6 15 ,,	......	......	27·79	3,077	54·2	51·5
	6 6 30 ,,	......	......	27·80	3,067	53·5	51·5
	6 8 0 ,,	......	......	27·90	2,967	53·5	51·5
	6 8 30 ,,	......	......	28·00	2,867	53·5	51·5
(11)	6 9 0 ,,	......	......	28·20	2,667	54·5	51·8
(12)	6 10 0 ,,						
(13)	6 13 0 ,,						
(14)	6 15 0 ,,						

Wolverhampton, September 5, 1862.

(15)	0 0 0 p.m.	29·40	60·0	29·40	490	59·5	54·2
(16)	1 3 20 ,,	29·17					
	1 5 0 ,,	29·17	......	......	720	59·0	54·5
(17)	1 5 10 ,,	28·97	......	29·10	909		
	1 5 20 ,,	......	......	29·05	909	57·2	53·5
	1.	2.	3.	4.	5.	6.	7.

(1) Began to get grapnel out.
(2) Rain on balloon ; a rainbow seen.
(3) A vertical rainbow visible.
(4) Over the Hermitage Plantation ; shouting
(5) Over Basingstoke Canal.
(6) Took down Mercurial Barometer.
(7) Over plantation.
(8) Over Woking Common ; sheep seen.
(9) Over corn-fields.
(10) Over farmhouse.
(11) Packed up instruments.
(12) Over meadows ; gas out.
(13) Over canal, and getting over clover-field.

Balloon Ascents. Crystal Palace, September 1, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
3·7	40·4							
4·7	39·5							
3·5	42·8							
3·3	43·7	......	......	......	......	......	43·5	
2·7	45·0							
2·0	45·9							
1·8	47·3							
2·0	47·1	......	......	......	......	......	46·0	
1·5	49·0							
1·5	49·0							
2·5	47·5							
2·7	47·8							
2·7	47·8	......	......	......	......	......	50·0	
2·8	48·3							
3·0	48·1							
3·0	48·3							
2·5	49·0	......	......	......	......	......	49·5	
2·5	49·0							
2·5	49·0							
2·7	48·9	......	......	......	......	......	48·0	
2·0	49·5							
2·0	49·5							
2·7	48·9							
2·7	48·9							
2·0	49·5							
2·0	49·5							
2·0	49·5							
2·7	49·2							

Wolverhampton, September 5, 1862.

5·3	49·5	59·5	59·2	54·3	4·9	49·9	49·0	45·5
4·5	50·5	59·0						
3·7	50·1							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(14) Reached the earth—two bumps; near the Hermitage Plantation, the property of — Lindsay, Esq. Rain had been falling nearly all the afternoon; during the whole time no ray of sun fell upon us; the sky was covered with clouds; the earth was very dark.

In this ascent the Barometers were read by Mr. MacDonald, who also took charge of Daniell's Hygrometer.

(15) Out of doors in shade, near Meter House. (16) Left the earth.

(17) Balloon spirating.

TABLE I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 1.	Height above sea-level.	Dry and Wet Ther.	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	1 5 30 p.m.	28·57	58·0	28·60	1,290		
(1)	1 5 50 „	......	......	......	......	56·5	52·5
	1 6 0 „	28·38	57·0	28·35	1,480	55·5	51·1
	1 10 0 „	26·19	55·0	26·20	3,660	45·5	43·5
	1 11 0 „	......	......	25·82	4,116	44·2	42·5
	1 11 30 „	25·491	54·0	25·62	4,388	......	......
	1 12 0 „	24·994	53·0	......	4,920	42·0	40·5
	1 12 30 „	24·894	......	......	5,011	41·0	39·8
	1 13 0 „	24·30	......	24·45	5,675	39·5	38·2
(2)	1 13 30 „	24·25	52·0	......	5,722	38·0	37·2
(3)	1 14 0 „						
(4)	1 14 30 „	23·70	......	23·90	6,330	36·5	36·5
(5)	1 16 0 „	23·35	50·0	23·40	6,729		
(6)	1 16 30 „	......	......	......	......	36·3	36·3
	1 17 0 „	23·20	50·0	......	6,914	......	......
(7)	1 17 20 „	......	......	......	......	38·2	36·1
(8)	1 17 40 „	22·658	49·0	22·71	7,575	39·0	35·2
(9)	1 21 0 „	20·717	46·0	20·60	9,926	33·5	31·1
(10)	1 22 0 „	20·070	45·0	20·17	10,770	31·1	30·5
	1 24 0 „	18·727	42·0	......	12,568	......	......
	1 25 30 „	17·931	......	18·10	13,715	25·5	25·0
	1 26 0 „	......	......	......	......	23·2	25·0
	1 27 0 „	16·936	38·0	16·90	15,184		
	1 27 30 „	......	......	......	......	17·2	23·
	1 28 0 „	16·686	36·0	16·65	15,510	......	......
(11)	1 28 30 „	......	......	......	......	16·5	19·0
	1 29 0 „	16·046	32·0	......	16,520	16·5	17·0
	1 29 20 „	......	......	15·82	......	......	......
	1 30 0 „	......	......	......	......	......	......
(12)	1 30 15 „	......	......	......	......	16·0	13·1
	1 30 30 „	......	......	......	......	......	......
(13)	1 32 0 „	15·38	30·0	......	17,590	15·0	12·1
(14)	1 34 0 „	......	......	......	......	......	......
	1 35 0 „	14·651	28·0	14·90	18,890		
	1 36 0 „	14·553	......	14·80	19,068		
	1 37 0 „	14·553	27·0	......	19,068	......	......
	1 37 10 „	......	......	......	......	15·0	11·1
	1 37 20 „	......	......	......	......	......	......
	1 37 30 „	14·469	......	14·80	19,222		
	1 37 40 „	......	......	14·40			
(15)	1 37 50 „	......	......	......	......	14·5	10·2
	1 38 0 „	......	......	......	......	......	......
	1 38 10 „	......	......	......	......	13·2	10·0
	1 38 20 „	14·947	30·5	......	19,960		
	1 38 25 „	......	......	14·28	20,126		
(16)	1 38 30 „	13·947					
	1 38 35 „						
	1 38 40 „	......	......	14·00			
	1.	2.	3.	4.	5.	6.	7.

(1) Misty. (2) In cloud, wholly obscured.

(3) Lighter. (4) Much lighter, still in cloud.

(5) Gun heard. (6) Dense cloud. (7) Out of cloud.

(8) Tried Camera upon beautiful clouds—failed; the balloon was spirating and ascending too quickly.

Balloon Ascents. Wolverhampton, September 5, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
4·0	47·9							
4·4	46·9							
2·0	41·2	......	46·0	43·8	2·2	41·3	......	42·0
1·7	40·4	44·2						
......	......	......	43·3	41·5	1·8	39·3	......	38·5
1·5	38·7							
1·2	38·3	40·7						
1·3	36·5	......	......	......	......	......	38·0	
0·8	36·1							
0·0	36·5	36·5						
0·0	36·3	36·0						
......	......	......	36·0	36·0	0·0	36·0	......	35·5
2·1	33·3	39·5						
3·8	30·2	40·0						
2·4	26·6	32·1						
0·6	28·9	31·2	......	......	......	......	......	25·0
......	......	26·5	24·5	23·0	1·5	14·5	......	25·0
0·5	22·3							
......	......	18·0						
......	......	17·9	17·0	24·0				
......	......	17·8	......	......	......	......	......	10·5
......	......	16·2						
2·9	− 9·2							
......	......	......	17·0	13·2	3·8	−15·7		
2·9	−10·3	15·5						
......	......	......	......	......	......	......	......	−5·5
......	......	15·6	15·5	11·3	4·2	−21·1		
3·9	−18·1							
......	......	15·8	......	......	......	......	− 8·0	
4·3	−13·0	......	......	......	......	......	−10·0	
......	......	......	14·2	10·5	3·7	−18·1		
3·2	−14·8	12·9						
8.	9.	10.	11.	12.	13.	14.	15.	16.

(9) Deep blue sky. (10) The ice not properly formed on Wet-bulb Thermometer.
(11) Earth visible in patches. (12) The Wet-bulb reads correctly.
(13) Ozone: Moffat 2; Moffat 2; Schönbein 0. (14) Mr. Coxwell pants for breath.
(15) Mercury of Daniell's Hygrometer invisible.
(16) Ozone: Moffat 3; Moffat second paper 3; Schönbein 1.

TABLE I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 1.	Height above sea-level.	Dry and Wet Ther.	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	1 38 50 p.m.	......	......	......	......	......	......
(1)	1 39 0 ,,	13·76	......	......	20,393	8·0	4·5
	1 40 0 ,,	......	......	......	......	......	......
	1 40 15 ,,	......	......	......	......	10·2	8·1
(2)	1 40 30 ,,	......	......	......	......	......	......
	1 41 20 ,,	13·35	26·0	......	21,182	......	......
	1 41 30 ,,	......	......	......	......	......	......
(3)	1 41 40 ,,						
(4)	1 41 50 ,,	......	......	......	......	......	......
(5)	1 44 0 ,,	12·754	......	......	22,380	8·1	4·2
(6)	1 45 0 ,,	......	......	......	......	......	......
(7)	1 48 0 ,,	11·954	25·0	......	23,976	0·0	−4·0
	1 50 0 ,,	11·254	......	......	25,382	......	......
(8)	1 51 0 ,,	10·803	......	......	26,350	−5·0	......
	1 53 ± ,,	9·753	......	......	29,000		
	2 7 0 ,,	......	......	11·53	25,318	−2·0	......
	2 8 0 ,,	12·354	......	......	23,021		
	2 8 30 ,,	12·554	......	12·80	22,654	......	......
	2 8 45 ,,	13·154	26·0	......	21,650	......	......
	2 9 0 ,,	14·054	......	......	20,018	17·0	11·0
	2 9 30 ,,	16·374	......	16·45	16,015	......	......
	2 9 40 ,,	17·074	......	......	14,938		
	2 10 0 ,,	......	......	......	......	22·5	15·8
	2 11 0 ,,	17·71	......	......	14,012		
	2 12 30 ,,	......	......	......	......	......	......
	2 14 0 ,,	18·05	......	......	13,520	......	......
	2 14 30 ,,	......	......	......	......	......	......
(9)	2 15 0 ,,	18·455	......	......	12,900		
	2 16 0 ,,	......	......	19·10	12,250	26·5	18·2
(10)	2 16 10 ,,	19·753	......	19·90	11,150		
	2 16 20 ,,	20·053	......	20·25	10,780		
(11)	2 16 50 ,,	20·653	27·0	20·65	10,070	31·1	23·1
	2 17 30 ,,	21·151	......	21·55	9,370		
	2 18 0 ,,	......	......	......	......	33·0	25·0
	2 19 0 ,,	......	......	......	......	34·2	25·9
	2 19 30 ,,	21·845	31·0	21·90	8,530		
	2 20 0 ,,	......	......	......	......	35·2	27·0
	2 20 20 ,,	22·041	33·0	......	8,310		
(12)	2 20 30 ,,	......	......	......	......	......	......
(13)	2 20 40 ,,	22·241	33·0	22·20	8,090	40·1	29·2
	2 21 30 ,,						
(14)	2 22 0 ,,	......	......	......	......	42·2	31·0
	2 22 10 ,,	......	......	......	......	......	......
(15)	2 23 20 ,,	22·637	35·0	22·76	7,625	42·0	......
	2 23 30 ,,	......	......	......	......	......	......
	2 23 50 ,,	22·932	37·0	23·20	7,260	......	......
	2 24 0 ,,	23·028	39·0	23·00	7,150		
	2 25 0 ,,	23·326	40·0	......	6,810	42·0	
	1.	2.	3.	4.	5.	6.	7.

(1) Sand out.
(2) Aspirator difficult to work.
(3) Ozone: Moffat 4.
(4) See with difficulty.
(5) Experienced a difficulty in reading the instruments.
(6) Aspirator troublesome.
(7) Sand out.
(8) Lost myself; could not see to read the instruments.
(9) Ozone: Moffat 5; Moffat second paper 5; Schönbein 2.

Balloon Ascents. Wolverhampton, September 5, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
......	......	8·0						
3·5	−22·7	8·5						
......	......	9·2	......	......	......	......	− 9·0	
2·1	− 8·2	......	......	......	......	......	......	−15·0
......	......	11·0	9·5	7·8	1·7	− 5·3		
......	......	......	......	......	......	......	......	−15·0
......	......	......	......	......	......	......	......	−20·0
......	......	4·5						
3·9	−26·0							
......	......	......	7·3	4·5	2·8	−17·3		
4·0	−35·2	......	......	......	......	......	......	no dew. −30·0
......	......	− 2·0						
......	......	− 5·0						
......	......	− 2·0						
......	......	+ 2·0						
......	......	11·0						
6·0	−34·7							
......	......	18·0						
6·7	−27·0							
......	......	23·2						
......	......	24·5						
......	......	......	24·8	18·0	6·8	−19·6		
8·3	−22·4							
8·0	+ 2·5	31·1						
8·0	9·3							
8·3	11·3							
8·2	13·9	35·2						
......	......	......	......	......	......	......	14·0	
11·9	15·2							
11·2	17·3							
......	......	40·0						
......	......	......	......	......	......	......	......	20·0
......	......	40·0						
......	......	40·0						
8.	9.	10.	11.	12.	13.	14.	15	16.

(10) Wind East. (11) Gun heard. (12) Sand out.

(13) Wet-bulb seems to be free from ice.

(14) After this observation I pressed the bulb of Wet Thermometer between my thumb and finger, for the purpose of melting any ice remaining on it, or on the connecting-thread.

(15) Ozone: Moffat's test 6.

TABLE I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 1.	Height above sea-level.	Dry and Wet Ther	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	2 26 0 p.m.	23·473	41·5	......	6,640		
	2 26 10 „	......	......	......	......	42·0	......
(1)	2 26 15 „	......	......	......	......	45·2	34·2
	2 27 0 „						
	2 29 0 „	......	......	......	......	......	......
	2 29 30 „	24·512	46·0	......	5,500	49·2	36·0
(2)	2 30 30 „	......	......	......	......	......	......
	2 31 0 „	......	......	......	......	49·0	......
	2 31 30 „	......	......	......	......	49·2	35·0
	2 32 0 „	25·401	50·0	25·55	4,521	......	......
	2 32 30 „	......	......	......	......	50·5	36·0
	2 33 0 „	25·800	50·0	......	4,110		
	2 33 30 „	......	......	......	......	51·1	37·0
	2 36 0 „	......	......	......	......	......	......
	2 38 0 „	26·399	50·0	26·35	3,484	53·0	45·0
	2 38 10 „	......	......	......	......	......	......
(3)	2 38 20 „						
	2 39 0 „	27·598	50·0	......	2,260		
	2 39 20 „	......	......	......	......	54·0	48·0
	2 39 40 „	......	......	28·10			
	3 6 0 „	......	......	29·02	......	57·2	52·8
Crystal Palace, September 8, 1862.							
(4)	4 47 0 p.m.	29·90	......	29·92	250	67·2	63·0
(5)	4 48 0 „	29·40	......	29·47	813	66·5	63·1
(6)	4 49 0 „	28·90	......	28·80	1,232	63·2	60·5
(7)	4 50 0 „	28·70	......	28·50	1,530	63·1	60·2
(8)	4 50 30 „	28·50	......	28·30	1,730	62·8	59·8
(9)	4 51 0 „	27·75	......	27·59	2,432	60·2	57·2
	4 52 0 „	27·55	......	27·40	2,520	58·8	56·5
(10)	4 52 30 „	27·20	......	27·10	2,923	56·5	54·2
(11)	4 53 0 „	26·90	......	26·70	3,320	55·2	52·5
	4 54 0 „	26·52	......	26·30	3,720	54·0	51·2
(12)	4 54 30 „	26·05	......	25·90	4,169	52·0	50·5
(13)	4 55 0 „	25·86	......	25·68	4,380	51·5	50·5
(14)	4 55 30 „						
	4 56 0 „	25·56	......	25·50	4,560	51·0	49·8
(15)	4 56 10 „						
(16)	4 56 30 „	25·46	......	25·41	4,650	50·5	49·8
	4 57 0 „	25·45	......	25·38	4,727	50·5	50·0
	4 57 30 „	25·43	......	25·38	4,727	50·8	49·8
(17)	4 58 20 „	25·44	......	25·36	4,750	51·1	49·8
	1.	2.	3.	4.	5.	6.	7.

(1) Wet-bulb seems to be correct; it has decreased from the reading I drove it to by the action of the heat of my thumb and finger.

(2) I do not think Aspirated Wet-bulb is correct.

(3) Ozone: Moffat's paper 7.

(4) At 4h 47m 15s eased up; at 4h 47m 28s let go catch.

(5) At 4h 48m 15s over the lake.

(6) Gas clear; at 4h 49m 55s scud at lower elevation, not under us.

(7) Thames seen clearly; ships seen.

(8) Sand out.

Balloon Ascents. Wolverhampton, September 5, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
……	……	41·5						
11·3	21·5							
……	……	45·5	……	……	……	……	……	27·0
13·2	21·8							
……	……	……	47·1	44·1	3·0	40·7	29·5	
……	……	47·0						
14·2	19·7							
……	……	48·0						
14·5	20·8							
14·1	22·3							
……	……	……	……	……	……	……	……	37·5
8·0	37·0	51·5						
……	……	53·0	53·5					
6·0	42·1	54·0						
4·4	48·8	57·5						

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8.	9.	10.	11.	12.	13.	14.	15.	16.
4·2	61·2							
3·4	60·4							
2·7	58·2							
2·9	57·8							
3·0	57·2							
3·0	54·6							
2·3	54·4							
2·3	52·1							
2·7	49·9							
2·8	48·5							
1·5	49·0							
1·0	49·5							
1·2	48·6							
0·7	49·1							
0·5	49·5							
1·0	48·8							
1·3	48·6							

(9) Gas getting cloudy; just see netting; smell of gas.
(10) Gas cloudy. (11) Heard shouting below.
(12) Mist; dense fog; gas cloudy; netting invisible.
(13) In a dense white cloud; can just see the earth.
(14) Earth not visible.
(15) In cloud, thick and white; dropped a piece of paper, visible 23 seconds.
(16) Gas still cloudy. (17) Half out of cloud; blue sky above.

Table I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	4 58 40 p.m.	25·44	……	25·36	4,750	50·5	49·8
(1)	4 59 0 "	25·50	……	25·42	4,690	50·3	49·2
(2)	4 59 10 "						
	4 59 30 "	……	……	25·50	4,610	49·5	48·7
	4 59 45 "	25·80	……	25·55	4,560	49·3	48·5
(3)	5 0 0 "	25·84	……	25·60	4,510	49·5	48·2
(4)	5 0 30 "						
	5 1 0 "	26·04	……	25·73	4,480	50·0	48·0
(5)	5 1 30 "						
(6)	5 1 40 "						
(7)	5 1 50 "						
	5 2 0 "	……	……	25·95	4,160	49·8	49·0
	5 3 0 "	……	……	26·10	3,946	50·5	49·8
	5 4 0 "	……	……	26·20	3,850	50·8	49·9
(8)	5 4 30 "	……	……	26·28	3,770	51·2	50·0
	5 5 0 "	26·55	……	26·38	3,670	51·5	50·8
	5 5 30 "	26·76	……	26·70	3,350	52·2	51·1
	5 6 0 "	26·81	……	26·74	3,310	52·5	51·5
	5 6 30 "	26·86	……	26·78	3,270	53·0	51·5
(9)	5 7 0 "	……	……	26·68	3,370	53·5	51·5
	5 7 30 "	26·63	……	26·25	3,808	53·5	51·5
(10)	5 9 10 "						
	5 10 0 "	……	……	26·10	3,958	52·5	51·5
(11)	5 10 30 "	……	……	25·95	4,108	52·2	51·5
(12)	5 10 40 "						
	5 11 0 "	26·85	……	25·74	4,220	51·5	50·0
(13)	5 11 15 "						
(14)	5 11 20 "						
(15)	5 11 25 "						
	5 11 30 "	26·66	……	25·52	4,440	51·0	49·8
(16)	5 11 55 "						
(17)	5 12 0 "	25·40	……	25·40	4,540	51·0	46·1
	5 12 15 "	……	……	25·22	4,895	51·0	44·1
(18)	5 12 30 "	……	……	25·20	4,920	51·1	44·2
	5 13 0 "	25·10	……	25·20	4,920	52·1	43·8
	5 14 0 "	……	……	25·20	4,920	53·2	44·1
(19)	5 14 40 "						
	5 15 0 "	……	……	25·19	4,930	54·2	44·1
	5 15 30 "	24·96	……	25·11	5,026	55·2	44·1
(20)	5 15 35 "						
	5 16 0 "	……	……	25·00	5,175	56·5	45·1
(21)	5 16 30 "						
(22)	5 16 45 "						
(23)	5 17 0 "	24·76	……	24·92	5,263	57·2	46·1
	1.	2.	3.	4.	5.	6.	7.

(1) Still partly in cloud.
(2) Cloud more dense; descending.
(3) See the roads on the earth.
(4) Can see the earth as through a fine mist.
(5) A misty view; horizon obscured all round.
(6) Can see Blackheath, the Royal Observatory, Woolwich, and the Crystal Palace.
(7) Very black clouds over London.
(8) Mouth of the Thames visible.
(9) Shouting below; dropped a piece of paper, visible for 2^m 45^s. A beautiful break in the clouds in the west.
(10) Over woods.
(11) Shooters Hill visible.
(12) In slight mist.
(13) Just see the earth.
(14) Earth invisible.

Balloon Ascents. Crystal Palace, September 8, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
0·7	49·1							
1·1	48·0							
0·8	47·9							
0·8	47·7							
1·3	46·8							
2·0	45·9							
0·8	48·2							
0·7	49·1							
0·9	48·9							
1·2	48·8							
0·7	50·1							
1·1	50·0							
1·0	50·5							
1·5	50·0							
2·0	49·5							
2·0	49·6							
1·0	50·5							
0·7	50·8							
1·5	48·5							
1·2	48·8							
5·0	40·8							
6·9	36·9							
6·9	37·0							
8·3	35·4							
9·1	34·9							
10·1	34·2							
11·1	33·5							
11·4	34·5							
11·1	35·9							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(15) Blue sky in zenith, clouds below; came out of cloud in a hollow or basin.
(16) Image of balloon with beautiful prismatic colours on the clouds.
(17) Sun shining; clear blue sky.
(18) Deep blue sky; beautiful reflexion of the balloon, with primary and secondary prismatic rings.
(19) Sun warm; clouds heaped upon others; we are not much higher than level of top of clouds.
(20) Gas rather cloudy; see netting pretty well.
(21) Earth seen through the clouds. (22) Fluffy clouds.
(23) Ring cut the spectral balloon about one-third from top.

TABLE I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther.	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	5 17 30 p.m.	......	......	24·95	5,230	57·2	47·2
(2)	5 17 55 „						
(3)	5 18 30 „	......	......	24·78	5,428	58·5	49·0
	5 19 0 „	25·10	......	24·82	5,388	60·0	49·5
(4)	5 20 30 „	......	......	25·05	5,112	58·2	
(5)	5 20 55 „						
	5 21 0 „	......	......	25·05	5,109	57·5	46·2
	5 21 10 „	25·36	......	25·02	5,145	57·5	46·2
(6)	5 21 20 „	......	......	25·00	5,169	57·5	46·2
(7)	5 21 50 „						
(8)	5 22 0 „	25·03	......	25·08	5,057	56·2	47·0
	5 22 40 „	25·30	......	25·09	5,043	54·2	47·8
(9)	5 22 45 „						
(10)	5 23 50 „	......	......	25·10	5,029	51·8	48·0
	5 24 0 „	......	......	25·11	5,019	51·5	48·2
(11)	5 24 10 „						
(12)	5 24 30 „	25·32	......	25·09	5,039	51·5	48·2
	5 25 0 „	......	......	25·30	4,829	51·2	48·5
(13)	5 25 20 „						
	5 25 30 „	25·70	......	25·50	4,629	51·2	49·5
(14)	5 25 55 „						
(15)	5 26 0 „	......	......	25·92	4,137	51·2	49·8
	5 26 20 „	......	......	26·69	3,328	52·0	49·5
(16)	5 26 25 „						
(17)	5 27 0 „	......	......	26·80	3,218	52·2	49·5
	5 27 30 „	26·64	......	26·40	3,618	52·5	49·5
(18)	5 27 55 „						
	5 28 0 „	26·65	......	26·58	3,438	53·5	51·5
(19)	5 28 8 „						
	5 29 30 „	27·34	......	27·06	2,954	54·5	52·0
(20)	5 29 55 „						
(21)	5 30 15 „						
(22)	5 30 25 „						
	5 30 30 „	27·50	......	27·25	2,783	55·0	52·5
	5 31 0 „	......	......	27·52	2,540	55·5	53·2
	5 31 30 „	......	......	27·60	2,432	55·5	54·2
	5 31 45 „	......	......	27·68	2,360	56·0	54·8
	5 32 0 „	28·17	......	27·82	2,207	56·2	55·1
(23)	5 32 5 „						
	5 32 30 „	......	......	27·95	2,090	56·2	55·1
	5 33 0 „	......	......	28·05	1,990	56·8	55·5
	5 33 15 „	28·44	......	28·17	1,870	57·2	55·9
	5 33 30 „	......	......	28·30	1,720	57·2	56·0
	5 34 0 „	......	......	28·40	1,620	57·2	56·2
	1.	2.	3.	4.	5.	6.	7.

(1) Clouds rising, were whiter than those below; a slight amount of blue in all clouds

(2) Balloon approaching clouds.

(3) Rings encircling the whole spectral balloon; there were three distinct rings round the balloon and car.

(4) Clouds near us like smoke.

(5) Rings just encircled the spectral car.

(6) Cold to senses.

(7) Rings just cut off top of the spectral balloon; beautiful chasm in the clouds.

(8) Entering cloud.

(9) Just entering cloud, blue sky above.

(10) Gas escaping out of balloon; sun visible; train heard; dog barking.

Balloon Ascents. Crystal Palace, September 8, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
10·0	38·0	……	……	……	……	……	42·0	
9·5	40·5							
10·5	40·3							
11·3	35·9							
11·3	35·9							
11·3	35·9							
9·2	38·4							
6·4	41·6							
3·8	44·2							
3·3	44·9							
3·3	44·9							
2·7	45·7							
1·7	47·7							
1·4	48·4							
2·5	47·0							
2·7	46·8							
3·0	46·5							
2·0	49·5							
2·5	45·5							
2·5	50·1							
2·3	51·2							
1·3	53·0							
1·2	53·7							
1·1	54·1							
1·1	54·1							
1·3	54·3							
1·3	54·7							
1·2	54·9							
1·0	55·3							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(11) Just in cloud again.

(12) In cloud, sky bluish above; hear sounds below; white mist.

(13) In cloud; gas very clear.

(14) Fields visible on the earth.

(15) Shouting.

(16) Cumulus scud below us.

(17) Saw embankment of London and Chatham Railway.

(18) A fine white cloud seemed to be resting on the Thames; Crystal Palace visible.

(19) Over Jorden's Wood, near Bexley.

(20) Over ploughed fields.

(21) Gun and shouting heard.

(22) Gravesend and the Nore in sight.

(23) Near Dartford.

TABLE I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	5 35 0 p.m.	……	……	28·49	1,530	58·2	57·0
(1)	5 35 30 ”	28·74	……	28·60	1,420	58·5	57·5
(2)	5 35 40 ”						
	5 36 0 ”	……	……	28·65	1,370	58·5	57·5
(3)	5 36 20 ”						
(4)	5 37 0 ”	……	……	28·80	1,220	59·0	58·5
	5 37 30 ”	……	……	28·95	1,077	59·8	58·0
(5)	5 38 10 ”						
	5 38 30 ”	……	……	29·10	932	60·0	59·8
	5 39 0 ”	29·40	……	29·20	842	60·2	59·8
	5 39 15 ”	……	……	29·25	805	60·5	59·5
	5 39 30 ”	29·42	……	29·30	768	60·5	59·8
	5 40 0 ”	29·40	……	29·28	782	61·0	60·5
(6)	5 40 15 ”						
(7)	5 40 20 ”						
	5 40 25 ”						
	5 40 30 ”	……	……	29·20	842	61·5	61·0
	5 41 0 ”	29·36	……	29·18	856	61·1	61·0
(8)	5 41 45 ”						
	5 42 0 ”	……	……	29·15	887	61·1	60·5
	5 43 0 ”	29·35	……	29·15	887	61·1	60·5
	5 44 0 ”	29·40	……	29·15	887	61·1	60·5
	5 44 30 ”	……	……	29·20	842	61·1	60·0
	5 45 0 ”	29·40	……	29·22	827	61·5	60·0
	5 45 30 ”	29·45	……	29·25	805	61·7	60·0
	5 46 0 ”	29·38	……	29·20	842	62·0	60·0
	5 47 0 ”	……	……	29·18	856	61·5	60·0
	5 48 0 ”	……	……	29·15	887	61·5	60·0
	5 48 30 ”	……	……	29·15	887	61·2	59·8
(9)	5 48 45 ”						
	5 49 0 ”	……	……	29·14	896	61·2	60·0
	5 49 10 ”	……	……	29·18	856	61·2	59·8
(10)	5 49 20 ”						
	5 50 0 ”	……	……	29·18	856	61·1	60·0
	5 50 30 ”	29·40	……	29·21	826	61·1	59·8
	5 51 0 ”	……	……	29·28	772	61·1	59·8
	5 52 0 ”	……	……	29·38	672	61·5	60·0
(11)	5 52 15 ”						
(12)	5 53 25 ”						
	5 54 0 ”	……	……	29·50	553	61·5	60·0
	5 54 30 ”	29·62	……	29·54	517	62·0	60·5
(13)	5 54 45 ”	……	……	29·46	589	62·0	60·5
(14)	5 55 0 ”	29·25	……	29·12	895	62·2	60·5
	5 55 10 ”	……	……	29·00	1,040	62·2	60·5
	5 56 0 ”	29·11	……	28·90	1,130	61·8	60·0
	5 56 10 ”	……	……	……	……	61·5	59·8
(15)	5 56 15 ”						
	5 56 40 ”	28·65	……	28·50	1,520	61·1	58·9
	1.	2.	3.	4.	5.	6.	7.

(1) North Kent train, eight carriages. (2) Flock of sheep, like large specks.
(3) Nearly over Small Wood.
(4) Could plainly see people waving handkerchiefs.
(5) Over very large wood. (6) Still over same wood.
(7) Crystal Palace still in sight. (8) See dog, and hear him barking and people shouting.

Balloon Ascents. Crystal Palace, September 8, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
1·2	55·8							
1·0	56·6	......	......	......	......	......	55·0	
1·0	56·6							
0·5	58·0							
1·8	56·5							
0·2	59·6							
0·4	59·5							
1·0	58·6							
0·7	59·2							
0·5	60·1							
0·5	60·6							
0·1	61·0							
0·6	59·9							
0·6	59·9	......	......	......	......	......	58·5	
0·6	59·9							
1·1	59·0							
1·5	58·7							
1·7	58·5							
2·0	58·3							
1·5	58·7							
1·5	58·7							
1·4	58·6							
1·2	58·9							
1·4	58·6							
1·1	59·0							
1·3	58·6							
1·3	58·6							
1·5	58·7							
1·5	58·7							
1·5	59·2							
1·5	59·2							
1·7	59·0							
1·7	59·0							
1·8	58·5							
1·7	58·2							
2·2	57·0							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(9) Over North Kent Railway. (10) Near large limeworks.
(11) Gas clear; over Swanscomb Marsh. (12) Bank of river Thames.
(13) People on steamboats energetic.
(14) Crossed the river in $2^m\ 1^s$ from bank to bank to the W. of Gravesend.
(15) Over London and Southend Railway.

TABLE I.—Meteorological Observations made in Eight

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther.	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	5 56 55 p.m.						
	5 57 0 „	……	……	28·40	1,628	60·8	58·2
	5 57 30 „	……	……	28·38	1,639	60·5	58·0
	5 58 0 „	28·40	……	28·22	1,798	60·0	58·0
(2)	5 58 15 „						
	5 58 40 „	……	……	……	……	60·0	58·2
	5 59 0 „	……	……	28·11	1,907		
	6 0 0 „	28·37	……	28·05	1,967	60·5	58·1
(3)	6 0 4 „						
	6 0 10 „	……	……	27·98	2,034	60·0	58·5
	6 0 20 „	28·18	……	27·98	2,034	60·0	57·8
	6 1 0 „	……	……	27·98	2,034	59·8	57·2
	6 1 30 „	……	……	27·90	2,114	59·8	57·5
	6 1 45 „	……	……	27·90	2,114	59·8	57·2
	6 2 0 „	……	……	27·78	2,235	59·5	57·1
(4)	6 3 4 „						
(5)	6 3 25 „						
(6)	6 4 15 „						
	6 5 0 „	……	……	27·89	2,122	59·2	57·0
(7)	6 6 0 „						
(8)	6 10 0 „	……	……	30·07			
	1.	2.	3.	4.	5.	6.	7.

(1) Over meadows opposite Rosherville Gardens; gas clear.
(2) Tilbury Fort examined with a telescope.
(3) Over Mucking Flats.
(4) Let gas out.
(5) Over meadows.

Balloon Ascents. Crystal Palace, September 8, 1862.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
2·6	56·0							
2·5	55·8							
2·0	56·2							
1·8	56·6							
2·4	56·0							
1·5	57·1	......	......	......	......	......	56·5	
2·2	55·8							
2·6	54·9							
2·3	54·8							
2·6	54·9							
2·4	50·0							
2·2	55·0							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(6) Descending. (7) Packed the instruments up.

(8) Down in Mucking Flats, about 2½ miles from Stanford le Hope, and 4 miles from Tilbury Fort.

§ 4. ADOPTED TEMPERATURES OF THE AIR AND DEW-POINT, WITH HEIGHT, IN THE EIGHT BALLOON ASCENTS.

From all the observations of the temperature of the air and of the dew-point in the preceding Tables, a determination was made of both elements with the corresponding readings of the barometer and heights. Some of the numbers in the column for heights have been interpolated when either of these elements have been observed without a corresponding observation of the barometer. The numbers thus found are within brackets. The results are contained in the following Tables.

TABLE II.—Showing the adopted Reading of the Barometer, calculated Height above the Sea, Temperature of the Air, and Temperature of the Dew-point in eight Balloon Ascents.

FIRST ASCENT.—July 17.

Time of observation. A.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.	Time of observation. A.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.
h m	in.	feet.	°	°	h m	in.	feet.	°	°
9 42	29·19	490	59·0	51·4	10 39	14·63	19380	36·5	21·6
47	26·01	3835	45·0	35·3	44	14·63	19336	34·0	21·3
49	25·22	4467	43·0	32·0	47	14·13	20238	31·5	14·6
51	24·14	5802	34·8	32·1	48	....	(20512)	31·0	
53	22·42	7980	32·5	....	50	13·64	21059	23·8	−12·5
54	20·02	8065	31·8	27·8	54	13·14	21792	19·0	−8·2
55	21·58	8809	29·8	21·8	57	12·14	23949	17·5	−4·5
56	20·93	9598	26·2	17·6	11 0	11·74	24746	16·0	−8·0
58	19·63	11312	26·0	24·5	1+	11·14	26177	16·0	−9·0
10 2	19·28	11792	26·0	24·4	3	11·64	25022	16·0	−8·5
3	18·63	12709	26·0	20·8	5	11·64	25028	17·5	
4	....	(13088)	26·2	19·9	7	11·64	25077	18·0	
5	18·14	13467	28·0	23·7	12	11·95	24547	23·7	
8	17·24	14544	31·0	23·8	20	12·65	23868	27·0	
11	16·74	15704	31·6	22·7	25	13·14	22337	27·2	
15	16·04	16914	32·0	22·7	37	16·36	16282	29·7	9·4
25	14·94	18844	37·2	24·6	38	18·94	12376	34·2	7·4
27	14·64	19374	36·1	23·1	39	20·04	10539	37·0	
29	14·64	19415	38·2	21·8	40	20·54	9882	37·8	19·8
30	14·64	19415	38·1	20·2	44	23·44	6330		
35	14·64	19485	42·2	19·5	45	24·24	5432		

Between 10h 50m and 11h 25m in the last column, the numbers entered with the sign — before them imply that the temperature of either Daniell's or Regnault's hygrometer had been lowered to the degree stated, but that no dew was deposited, and therefore that the temperature of the dew-point was at a still lower degree.

At 10h 50m the readings of the Dry and Wet (free) were 24°·5 and 17°·2, giving a dew-point temperature of —26°·6.

At 10h 50m the readings of the Dry and Wet (aspirated) were 23°·0 and 17°·0, giving a dew-point temperature of —20°·6.

At 10h 54m the readings of the Dry and Wet (free) were 19°·2 and 11°·2, giving a dew-point temperature of —47°·5.

At 10h 57m the readings of the Dry and Wet (free) were 16°·5 and 9°·5, giving a dew-point temperature of —44°·1; and the readings of the Dry and Wet (aspirated) were 18°·5 and 8°·0, giving a dew-point temperature of —69°·9.

At 11ʰ 7ᵐ the readings of the Dry and Wet (free) were 19°·0 and 9°·0, giving a dew-point temperature of −67°·4; and the readings of the Dry and Wet (aspirated) were 18°·2 and 12°·0, giving a dew-point temperature of −34°·5.

At 11ʰ 25ᵐ the readings of the Dry and Wet (free) were 28°·1 and 17°·5, giving a dew-point temperature of −26°·1.

From the general agreement of the results observed by Daniell's Hygrometer to −10°, by Regnault's Hygrometer to this and lower temperatures, and those of the dew-point as found by the Dry- and Wet-bulb thermometers, there can be no doubt that the temperature of the dew-point at heights exceeding 25,000 feet must have been at least as low as −50°.

SECOND ASCENT.—July 30.

Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.	Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.
h m s	in.	feet.	°	°	h m s	in.	feet.	°	°
4 36	29·96	250	68·2	50·0	5 18	24·93	5220	49·3	37·3
40	29·96	250	68·0	49·7	20 30	24·78	5370	48·2	37·3
40 30	29·87	330	67·2	48·0	21	24·79	5360	48·5	37·2
40 45	29·82	370	66·5	47·9	22	24·95	5200	49·8	38·9
41	29·80	390	66·5	47·9	23 30	24·95	5200	48·5	37·2
41 15	29·65	480	66·0	47·9	24	24·82	5330	50·0	38·7
41 30	29·55	570	65·5	47·3	24 30	24·70	5450	47·5	35·9
42	29·50	615	65·2	45·1	26	24·62	5830	47·8	35·8
42 30	29·20	890	63·8	44·9	28 30	24·32	5530	48·0	35·4
43	28·85	1189	62·0	43·2	31	24·47	5380	48·5	36·2
43 30	28·65	1389	62·0	43·0	31 30	24·57	5280	48·2	38·4
44 30	28·20	1829	59·8	43·5	38 30	24·30	5903	43·5	35·8
45 30	27·65	2379	58·5	42·6	39	24·22	5983	43·5	35·8
47 30	27·10	2452	54·2	41·9	40 30	24·02	6183	43·5	35·8
48 30	26·87	3161	52·5	41·4	41	....	(6220)	44·1	34·0
49	26·50	3543	51·0	39·8	43	23·83	6370	44·2	32·7
50	26·40	3640	50·4	40·4	44	24·00	6252	45·2	35·1
50 30	26·35	3690	49·8	41·0	45 30	24·42	6785	46·5	35·9
52	26·27	3770	50·0	39·7	47	24·60	5577	46·0	36·4
52 30	26·25	3790	50·6	40·7	48	24·53	5649	45·2	35·1
53 30	26·18	3860	51·0	40·0	50	24·35	5846	44·2	34·7
54	26·12	3920	52·2	39·7	52	24·12	6102	43·0	33·1
54 30	26·08	3960	52·5	39·4	54	23·82	6466	46·0	34·3
56	25·91	4169	51·5	40·3	55	23·69	6642	46·5	33·8
56 45	25·80	4279	50·0	39·7	57	23·58	6752	47·2	35·2
57 30	25·73	4358	50·5	39·2	57 30	23·50	6826	43·5	31·4
59	25·78	4308	50·5	39·2	58	23·47	6856	43·1	32·6
59 30	25·85	4234	51·5	40·3	58 30	23·43	6896	43·5	31·4
5 0	25·90	4184	51·8	40·1	59	....	(6910)	43·9	29·8
0 30	26·00	4084	51·8	40·1	6 0	23·40	6937	42·5	30·3
1	....	(4094)	51·5	39·9	1	23·47	6867	41·0	32·0
1 30	25·98	4104	52·1	40·2	2	23·79	6547	41·5	31·4
3	25·76	4324	51·5	40·7	6	....	(6603)	45·6	31·6
4 30	25·68	4403	52·1	39·8	7	....	(6617)	45·2	32·9
7 30	25·47	4613	49·2	36·5	7 30	....	(6625)	45·0	32·4
8	25·30	4783	49·0	36·7	8 30	23·70	6637	45·0	31·3
9 30	25·40	4682	48·5	38·1	10 30	23·59	6747	44·8	29·0
10	25·35	4733	48·9	37·7	11 30	23·40	6937	44·2	31·8
11 30	25·20	4925	48·2	37·5	13	23·42	6917	44·2	31·8
12	25·20	4920	48·5	37·2	14	....	(6819)	44·5	30·8
14	25·26	4863	48·2	37·3	15	23·63	6720	44·5	32·4
16	25·25	4873	48·2	38·0	17	....	(6505)	45·5	32·5
16 30	25·20	4920	47·9	37·6	18	23·95	6400	45·2	32·7
17 30	25·00	5155	49·3	36·2	18 30	24·35	6000	46·4	32·8

SECOND ASCENT.—July 30 (*continued*).

Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.	Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.
h m s	in.	feet.	°	°	h m s	in.	feet.	°	°
6 19	24·55	5800	46·0	34·3	6 23	26·48	3870	49·2	39·5
19 30	24·60	5750	46·2	36·2	24	26·60	3750	50·1	41·7
20	24·95	5400	47·0	35·4	25	27·65	2700	55·5	42·2
21	25·40	4950	47·5	37·0	25 30	....	(2400)	58·3	41·7
22	25·90	4450	47·8	38·8	30	29·96	on the ground	68·0	47·4
22 30	....	(4160)	49·0	38·6					

THIRD ASCENT.—August 18.

P.M.					P.M.				
0 53 0	29·34	490			1 52 30	25·59	4448		
56 0	29·34	490	67·8	54·6	53 0	....	(4562)	52·2	40·0
1 5 0	28·84	1130	62·5	52·5	55 0	25·08	5019	51·0	42·0
6 0	28·55	1419	60·0		56 0	....	(5273)	..	39·5
6 20	28·25	1713	58·2	53·1	57 40	....	(5695)	50·0	40·9
6 30	....	(1795)	57·2		58 0	24·39	5780		
7 0	27·90	2042	55·5	50·5	58 30	....	(5913)	54·8	
8 0	26·67	3347			58 40	....	(5958)	..	40·1
8 20	....	(3466)	52·5		2 0 0	23·93	6313		
9 0	26·27	3705	50·0	49·6	1 0	23·78	6491		
10 0	25·86	4138	49·9		1 30	....	(6580)	54·0	41·7
10 25	....	(4440)	49·8	44·2	9 0	22·58	7886	50·5	38·6
11 0	25·30	4767	48·8	42·2	10 0	....	(8342)	..	37·5
11 30	....	(5140)	48·6		10 30	22·18	8571	51·0	39·8
12 0	24·60	5509	48·2		11 0	....	(8660)	51·0	38·4
12 30	24·60	5510	47·8	38·8	11 40	21·88	8771	51·0	37·6
13 20	....	(6155)	48·0	37·7	11 50	....	(8771)	..	39·0
14 0	23·64	6585	46·5		12 0	....	(8771)	..	39·0
15 0	22·69	7706	45·7		12 20	....	(8771)	..	39·5
17 0	21·69	8935	44·0	32·0	13 0	21·88	8771		
18 45	20·90	9954	43·0	29·6	13 40	....	(9327)	50·5	
18 55	....	(10129)	40·5	28·6	13 50	....	(9715)	..	34·9
20 0	19·90	11267	38·5		14 0	20·99	9902	50·0	
20 5	....	(11285)	37·2	24·9	15 0	21·14	9695	50·5	34·1
20 35	19·80	11399	36·0	24·8	15 30	....	(9987)	48·1	
21 0	19·75	11470	39·5	22·2	17 0	20·24	10864	..	29·3
22 0	20·30	10840	41·8	25·2	20 0	19·60	11748	..	21·2
24 0	20·90	9884	45·0	26·9	21 0	19·11	12364	39·2	25·6
24 5	....	(9884)	45·0		22 0	....	(12595)	38·5	
24 15	20·90	9884	..		22 30	18·86	12708		
24 50	21·38	9120	46·2	32·0	23 0	18·71	12942	38·0	
25 0	....	(9040)	45·8		24 0	18·11	13852	34·1	
25 10	....	(8960)	47·2	33·1	25 0	....	(14290)	..	23·4
26 0	....	(8575)	..	28·2	25 20	17·61	14434	..	23·1
26 30	22·21	8342	..	30·5	29 0	16·41	16339	27·8	6·0
27 0	22·62	7836	51·0	37·9	31 0	....	(16885)		
32 0	22·80	7650	49·2	37·0	32 0	15·93	17157		
33 0	22·80	7650	53·8	36·6	32 10	....	(17240)	..	± 5·0
34 0	....	(7265)	..	36·0	32 20	15·84	17321	28·1	
37 30	24·25	5919	..		32 30	....	(17380)		
38 0	24·46	5820	53·8	37·8	34 0	....	(17770)	30·5	5·0 no dew
41 0	25·08	5028	53·5						
41 30	25·56	4530	..	43·5	34 20	....	(17860)	..	3·5 no dew
43 0	25·58	4480	..	46·0					
46 0	26·56	3438	..	47·5	35 0	....	(18039)	31·5	1·2
48 0	26·76	3219	56·0		36 10	....	(18445)	27·5	− 5·0
52 0	25·79	4233	55·0		36 20	....	(18505)	28·0	

Third Ascent.—August 18 (*continued*).

Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.	Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.
h m s	in.	feet.	°	°	h m s	in.	feet.	°	°
2 36 30	15.03	18560			3 12 30	12.93	22705	24.0	
36 40	....	(18605)	24.8	− 2.0	13 0	....	(22160)	..	− 9.0
36 50	....	(18650)	25.5		13 13	13.63	21977	24.0	
37 55	....	(18935)			13 20	....	(22000)	..	−10.0
38 10	14.87	19000			13 30	....	(22004)	24.0	
38 30	....	(19200)	..	− 5.0	13 40	13.58	22008	24.0	
38 40	....	(19290)	28.5		18 30	13.45	22107	24.0	
39 0	14.62	19461			19 20	....	(21757)	..	−10.0
39 10	....	(19604)			19 30	....	(21685)	24.0	
39 20	....	(19800)	26.1		19 40	....	(21615)	25.0	
39 30	....	(20000)	25.5		19 40	....	(21610)	24.8	
42 0	....	(20350)	..	− 8.5	32 0	....	(16405)	..	0.0
42 10	14.12	20359	25.1		33 0	16.78	15984		
45 0	....	(20665)	..	− 5.0	34 0	17.53	13320	32.8	11.1
....	....	(20888)	23.5		36 0	18.63	12453	38.0	13.3
49 0	13.62	21111			39 0	20.02	10624	40.7	14.4
49 50	....	(21200)	25.4	−10.0	40 0	20.72	10224	45.5	14.4
59 0	12.83	23164	..	−12.0	41 30	21.62	8764		
59 10	12.71	23215	24.2		43 0	22.77	8144		
59 20	12.61	23377	..	− 8.0	43 10	....	(7910)	50.5	36.7
59 40	12.93	22705	24.0	−10.0	43 30	22.74	7438		
3 0 0	13.13	22295			45 0	....	(6943)	..	38.6
3 20	13.13	22295	24.5	− 9.0	47 0	....	(6282)	..	40.0
....	....	(22295)	24.8	−10.0	49 0	24.28	5621	50.0	
4 30	13.13	22295	24.0	− 9.0	50 20	25.08	4821	52.1	43.9
5 0	12.93	22705	24.1		51 0	25.36	4521	51.5	44.8
5 30	....	(22705)	..	−10.0	53 0	....	(3900)	51.0	48.9
6 10	....	(22705)	24.0		4 5 0	....	on the ground	67.0	
7 0	12.93	22705	24.0	− 8.0					

Fourth Ascent.—August 20.

P.M.					P.M.				
6 5 0	29.86	250	67.8	56.7	6 43 0	25.68	4256	50.0	45.5
26 0	29.86	250	66.2	55.9	43 30	25.60	4316	51.0	45.3
27 0	29.85	250	66.0	56.0	47 0	25.55	4366	50.5	43.7
28 30	29.66	430	65.2	54.8	48 0	25.60	4316	50.0	43.8
29 0	29.62	450	64.6	54.3	49 0	25.75	4116	49.2	45.7
29 30	29.48	530	64.2	53.7	49 30	25.80	4055	50.5	46.4
29 40	29.40	602	64.1	53.3	50 0	26.05	3893	51.5	44.9
29 50	29.33	662	63.5	52.5	51 30	26.25	3693	51.5	44.9
30 0	29.28	707	63.2	52.7	52 0	26.35	3593	51.5	44.9
31 0	28.95	1037	63.0	52.3	55 0	26.28	3663	51.2	45.1
32 30	28.55	1397	61.5	51.7	56 0	26.25	3693	50.9	45.4
33 0	28.45	1497	61.5	51.3	57 30	26.20	3743	50.3	45.2
34 0	28.00	1912	58.5	50.5	58 0	26.15	3793	49.8	44.4
35 0	27.75	2160	57.5	49.1	7 0 0	26.11	3833	50.2	44.7
35 30	27.65	2257	56.2	50.0	1 20	26.08	3863	49.8	44.4
36 0	27.40	2408	56.0	49.2	2 0	26.05	3893	49.5	44.7
37 0	....	(2665)	55.2	49.1	4 0	25.85	4052	48.2	44.7
37 10	27.20	2709	55.1	49.0	5 0	25.70	4250	48.0	43.8
37 30	26.95	2959	54.2	48.8	7 0	25.58	4384	47.0	43.0
38 0	26.75	3159	53.1	48.9	8 0	25.60	4354	47.2	43.7
39 0	26.55	3359	52.8	48.2	9 0	25.68	4278	48.1	43.9
41 0	26.12	3816	51.1	46.6	10 0	25.50	3405	48.2	44.7
41 30	25.95	3986	50.5	46.4	12 0	26.20	3621	49.8	43.0
42 0	25.82	4116	51.0	45.9	13 0	26.45	3468	51.0	45.3

FOURTH ASCENT.—August 20 (*continued*).

Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.
h m s	in.	feet.	°	°
7 15 0	27·50	2398	53·5	48·5
16 0	27·70	2198	54·2	48·9
16 30	28·03	1871	54·8	49·3
17 0	28·25	1655	55·5	49·6
18 0	28·50	1417	56·5	50·1
19 0	28·53	1387	57·0	50·3
19 10	28·55	1367	57·0	50·3
19 30	28·63	1287	57·2	51·3
20 0	28·64	1277	57·5	51·2
20 30	28·62	1297	57·5	51·2
22 0	28·33	1587	57·8	51·0
23 0	28·25	1667	57·2	51·4
24 0	28·01	1907	56·8	50·5
25 0	27·85	2067	56·8	50·5
25 20	27·75	2167	56·2	50·2
26 0	27·70	2217	56·5	50·1
26 30	27·70	2217	56·5	50·7
28 0	27·78	2297	56·8	50·1
7 29 30	27·70	2217	55·9	50·1
30 0	27·58	2417	55·5	50·2
32 0	....	(2620)	55·2	51·3
33 0	27·18	2723	54·2	48·8
34 0	27·18	2723	54·8	49·3
35 0	27·22	2683	55·2	47·9
36 0	27·30	2603	54·8	48·5
37 0	....	(2670)	54·2	48·8
40 0	27·03	2873	53·5	46·1
41 0	26·80	3003	53·0	46·0
42 0	26·10	3703	51·2	44·7
47 0	24·82	5194	45·0	41·8
48 0	24·90	5106	45·0	41·8
49 0	24·18	5900	43·0	
52 0	24·88	5200	43·3	
55 0	24·88	5200	44·2	
56 0	24·92	5160	44·2	

FIFTH ASCENT.—August 21.

A.M.				
4 30 0	....	320	60·8	58·4
31 0	29·59	358	60·0	57·2
33 0	29·58	367	58·9	57·2
35 0	29·45	490	59·2	58·9
36 0	29·20	728	59·0	59·0
39 0	28·78	1130	57·8	52·2
40 0	28·70	1210	57·5	51·2
41 0	28·62	1286	57·2	50·6
42 0	28·58	1326	56·8	51·0
44 0	28·18	1706	55·5	51·2
45 0	27·90	2000	55·0	51·1
49 0	26·95	2930	52·2	47·4
51 0	26·40	3510	49·8	44·4
52 0	25·95	3951	47·0	41·0
53 0	25·78	4138	46·5	40·7
55 0	25·05	4927	43·8	41·5
55 30	24·72	5260	43·2	41·0
56 0	....	(5357)	42·0	40·2
57 0	24·45	5557	40·2	39·8
57 30	24·05	5989	39·7	39·7
5 0 0	23·58	6510	38·5	36·0
3 0	23·75	6336	40·7	32·3
4 0	23·68	6413	41·5	31·8
5 0	23·20	6967	40·5	32·5
7 0	23·15	7027	40·5	30·9
8 0	23·10	7087	41·0	29·2
10 0	22·48	7810	37·5	25·5
11 0	22·10	8281	37·2	24·7
12 0	22·00	8406	35·0	23·3
14 0	21·65	8841	35·2	21·2
15 0	21·40	9150	34·8	20·2
15 30	21·10	9525	33·0	18·6
16 0	20·65	10085	32·8	12·4
17 0	20·45	10335	31·9	10·1
18 0	20·30	10472	31·0	14·3
A.M.				
5 20 0	19·70	11222	29·8	
21 0	19·45	11616	27·8	
22 0	19·09	12254	25·5	
23 0	18·90	12421	23·2	
24 0	18·90	12421	23·3	
26 0	....	12851	23·5	
27 0	18·42	13080	24·0	
29 0	18·20	13381	24·0	− 7·1
29 30	18·15	13456	23·5	− 9·8
30 30	18·00	13665	25·0	− 6·3
31 0	17·90	13680	22·2	−23·4
32 30	17·82	13799	19·5	−29·4
34 0	17·78	13875	19·5	−23·4
34 30	17·78	13875	19·3	−39·4
35 0	17·70	14027	19·5	−30·6
36 0	17·72	13989	19·9	−36·2
36 30	17·71	14008	20·0	−22·6
37 0	17·70	14027	20·5	−21·5
38 0	17·65	14121	21·5	−19·5
38 30	17·62	14178	22·5	−22·1
40 0	17·68	14064	24·0	−17·5
42 0	17·68	14068	24·8	−17·5
43 0	17·62	14178	24·8	− 3·2
44 0	17·62	14178	25·2	− 4·4
44 30	17·62	14178	26·5	−14·4
45 0	17·58	14254	26·5	−13·2
45 45	17·58	14254	26·3	−12·4
46 0	17·58	14254	27·2	−12·4
46 15	17·58	14254	27·2	−12·4
47 0	17·56	14335	27·6	−13·1
48 0	17·57	14273	26·0	− 7·4
48 30	17·58	14254	25·5	
50 0	17·57	14273	25·5	−15·4
50 45	17·58	14254	25·1	−15·3
51 0	17·56	14318	25·2	−21·8

FIFTH ASCENT.—August 21 (*continued*).

Time of observation. A.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.	Time of observation. A.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.
h m s	in.	feet.	°	°	h m s	in.	feet.	°	°
5 52 0	17·60	14258	24·1	−12·5	6 24 0	22·23	8040	43·0	21·0
55 0	17·62	14228	23·8	−19·7	25 0	22·65	7655	42·8	20·1
56 0	17·62	14228	23·8	−17·7	25 30	22·72	7573	43·5	20·5
56 30	17·62	14228	23·0	−17·0	27 0	22·95	7293	44·5	19·6
57 0	17·62	14228	23·1	−20·5	27 30	23·08	7141	44·2	22·0
57 30	17·61	14243	22·5	−17·6	28 0	23·12	7094	43·0	25·8
58 0	17·60	14258	23·0	−24·3	28 30	23·11	7106	42·8	27·8
59 30	17·62	14228	23·4	−25·6	29 0	23·20	7001	43·0	30·2
59 30	17·62	14228	23·4	−27·5	30 0	23·30	6884	43·0	33·1
6 0 0	17·63	14213	23·5	−27·4	31 0	23·28	6907	42·0	38·7
1 0	17·70	14108	24·2	−29·0	31 30	23·40	6767	42·5	39·2
2 0	17·90	13802	24·5	−29·4	32 0	23·50	6650	42·0	38·7
2 30	17·95	13715	24·2	−17·0	32 15	23·60	6533	42·0	38·7
3 0	18·10	13484	23·8	−26·7	33 0	24·00	6058	41·5	37·7
4 0	18·11	13479	24·2	−19·0	33 30	24·22	5819	41·8	37·3
4 30	18·15	13419	24·2	−17·7	33 30	24·50	5515	41·5	37·7
5 30	18·23	13299	25·2	−17·3	34 0	24·70	5298	42·2	37·9
6 0	18·30	13194	25·2	−11·2	35 0	24·80	5189	43·5	38·0
6 15	18·35	13119	25·2	−13·1	36 0	24·90	5080	44·2	37·5
8 0	....	(12815)	24·5	−13·8	36 30	24·92	5058	43·8	39·2
12 0	19·07	12174	30·0	5·1	37 0	25·10	4851	45·2	37·2
12 20	19·11	12122	29·8	1·6	37 30	25·20	4745	45·0	38·9
13 0	19·15	12070	27·8	1·8	37 45	25·30	4639	45·0	38·9
13 30	19·28	11901	27·5	−12·6	38 0	25·60	4320	46·0	40·0
14 0	19·30	11875	27·8	− 5·4	38 30	25·92	3980	46·8	40·8
14 30	19·30	11875	27·5	−10·7	39 0	26·15	3751	47·8	41·6
15 0	19·30	11875	27·8	− 4·4	40 0	26·40	3502	48·2	42·6
16 0	19·65	11420	31·5	4·5	41 0	26·60	3300	49·5	44·7
17 0	19·80	11225	32·0	8·8	42 0	26·80	3186	50·0	45·5
18 0	20·05	10871	33·8	17·3	42 15	27·00	2872	51·0	45·3
18 15	20·20	10688	34·5	14·7	43 0	27·20	2673	51·5	44·8
18 30	20·30	10566	36·5	16·0	44 0	27·70	2177	53·5	46·7
19 0	20·80	9936	37·0	18·1	45 0	27·98	1898	54·5	48·0
20 0	21·00	9650	37·0	18·7	45 30	28·20	1684	55·5	48·6
22 0	21·70	8810	41·5	18·0	46 0	28·40	1489	56·0	47·8
23 30	22·20	8196	43·5	18·7	7 10 0	29·42	513	61·8	51·1

SIXTH ASCENT.—September 1.

P.M.					P.M.				
4 5 0	29·78	250	63·0	57·3	5 5 30	26·46	3408	49·2	40·1
40 0	29·78	250	63·8	56·5	6 30	26·41	3458	49·5	39·8
45 0	29·78	250	65·0	55·5	8 0	26·41	3458	49·5	38·5
52 0	....	270	64·0	56·3	9 0	26·50	3368	49·8	38·2
53 0	29·65	320	63·0	51·9	10 0	26·55	3318	50·0	39·3
53 20	29·20	720	61·1	52·5	10 30	26·51	3358	50·0	39·3
53 40	28·90	996	59·2	50·3	11 30	26·31	3560	50·0	39·3
54 0	28·55	1332	57·2	51·2	13 0	26·19	3680	48·8	37·8
54 30	28·00	1868	55·2	47·8	15 0	26·19	3680	49·2	38·6
55 0	27·65	2214	54·2	48·1	16 0	26·25	3620	49·2	38·4
57 0	27·21	2654	52·2	46·7	17 0	26·29	3580	49·2	38·6
58 30	26·92	2940	51·5	44·0	19 0	26·28	3590	48·8	37·0
59 0	26·91	2950	50·5	43·7	20 0	26·29	3583	47·8	37·3
5 1 0	26·78	3080	50·0	42·8	23 0	25·95	3937	47·2	38·3
1 30	26·69	3170	50·0	42·8	23 30	25·91	3977	47·2	36·4
3 0	26·61	3257	49·5	43·3	24 0	25·90	3987	47·0	36·6
4 0	26·60	3268	49·2	42·6	25 0	25·90	3987	47·2	37·2

SIXTH ASCENT.—September 1 (*continued*).

Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.	Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.
h m s	in.	feet.	°	°	h m s	in.	feet.	°	°
5 26 0	26·05	3837	48·1	36·4	5 56 0	27·55	2290	51·0	47·3
26 30	26·15	3737	48·2	38·4	57 0	27·65	2190	51·2	47·1
27 0	26·20	3687	48·5	38·0	57+	....	(2040)	52·0	49·0
28 0	26·10	3787	47·8	36·6	58 0	27·95	1890	52·0	49·0
29 0	26·00	3887	47·2	36·4	58 10	28·05	1790	52·5	47·5
30 0	25·88	4000	47·2	36·3	58 30	28·12	....	53·2	47·8
31 0	25·75	4090	47·2	36·4	59 0	28·22	1620	53·2	47·8
32 0	25·70	4180	46·2	36·1	59 30	28·30	1540	53·8	48·3
33 0	25·69	4190	46·2	36·1	6 0 0	28·45	1417	54·0	48·1
35 0	25·69	4190	46·1	36·0	0 30	28·52	1347	54·2	48·3
37 0	25·98	3900	47·2	37·9	2 0	28·30	1567	54·0	49·0
37 30	26·19	3690	47·2	37·2	3 0	28·19	1677	54·0	49·0
40 0	26·50	3362	47·5	38·4	3 30	28·05	1817	54·0	49·0
42 0	26·82	3040	48·5	39·6	4 0	27·81	2057	54·2	48·9
43 0	26·95	2910	49·2	41·6	5 0	27·75	3117	53·5	49·5
44 0	26·95	2910	49·8	42·2	5 30	27·75	3117	53·5	49·5
45 0	26·88	2970	49·2	42·8	6 0	27·75	3117	54·2	48·9
48 0	26·68	3170	48·2	40·4	6 15	27·79	3077	54·2	48·9
50 0	26·90	2950	49·2	39·5	6 30	27·80	3067	53·5	49·5
52 0	27·49	2356	50·0	42·8	8 0	27·90	2967	53·5	49·5
53 0	27·40	2446	50·5	43·7	8 30	28·00	2867	53·5	49·5
53 30	27·40	2446	50·5	45·0	9 0	28·20	2667	54·5	49·2
54 0	27·44	2406	50·0	45·9					

SEVENTH ASCENT.—September 5.

P.M.					P.M.				
0 0 0	....	490	59·5	48·4	1 30 15	....	(16965)	16·0	
1 5 0	29·17	720	59·0	50·5	30 30	....	(17055)	16·0	
5 20	28·97	909	57·2	50·1	32 0	15·40	17590	15·5	
5 50	....	(1340)	56·5	47·9	34 0	....	(18180)	....	− 5·5
6 0	28·38	1480	55·5	46·9	37 0	14·55	19068	15·6	−21·1
10 0	26·19	3660	45·5	41·5	37 20	....	(19290)	15·8	− 8·0
11 0	....	4116	44·2	40·4	38 0	....	(19735)	14·2	
11 30	25·49	4388	43·3	38·9	38 10	....	(19847)	12·9	
12 0	24·99	4920	42·0	38·7	38 20	14·05	19960		
12 30	24·89	5011	40·9	38·3	38 25	13·95	20126		
13 0	24·30	5675	39·5	36·5	38 50	....	(20315)	8·0	− 5·0
13 30	24·25	5722	38·0	36·1	39 0	13·76	20393	8·5	
14 30	23·70	6330	36·5	36·5	40 0	....	(20733)	9·2	− 9·0
16 0	23·36	6729			40 15	....	(20818)	....	−15·0
16 30	....	(6821)	36·1	36·1	40 30	....	(20903)	11·0	
17 0	23·21	6914	36·0	35·7	41 20	13·35	21182	....	−15·0
17 20	....	(7245)	..	33·3	41 50	....	(21407)	4·5	
17 40	22·66	7575	39·5	30·2	44 0	12·75	22380		
21 0	20·72	9926	32·1	26·6	48 0	11·95	23976	0·0	−30·0
22 0	20·07	10770	31·2	26·9	50 0	11·25	25382	− 2·0	no dew
24 0	18·73	12568	26·5	19·7	51 0	10·80	26350		
25 30	17·93	(13875)	25·5	22·3	53±	9·75	29000	− 5·0	
26 0	....	(14312)	23·2		2 7 0	....	25318	− 2·0	
27 0	16·94	15184			8 30	12·55	22654	+ 2·0	
27 30	....	(15347)	18·7		8 45	13·15	21650	11·0	
28 0	16·69	15510	18·0		9 0	14·05	20018	17·0	
28 30	....	(16015)	17·9		9 30	16·37	16015	18·0	
29 0	16·05	16520	17·9		9 40	17·07	14938		
29 20	....	(16640)	17·8	10·5	10 0	....	(14706)	22·5	
30 0	....	(16875)	16·2		11 0	17·71	14012		

SEVENTH ASCENT.—September 5 (*continued*).

Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.	Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.
h m s	in.	feet.	°	°	h m s	in.	feet.	°	°
2 14 0	18·06	13520	24·5		2 26 10	....	(6590)		
14 30	....	(13210)	24·8		26 15	....	(6560)	45·2	21·5
15 0	18·46	12900	..	0·0	29 0	....	(5655)	45·5	27·0
16 0	....	12250	26·5		29 30	24·51	5500	47·0	21·8
16 50	20·65	10070	31·1		30 30	....	(5110)	47·1	35·1
19 0	....	(8800)	34·2		31 30	....	(4720)	49·2	19·7
19 30	21·85	8530			32 0	25·40	4521	48·0	
20 0	....	(8400)	35·2		32 30	....	(4315)	50·5	20·8
20 20	22·04	8310			33 0	25·80	4110		
20 40	22·24	8090	40·1	15·2	33 30	....	(4050)	51·1	22·3
22 0	....	(7860)	42·2	17·3	36 0	....	(3735)	....	37·5
23 20	22·64	7625	40·0	20·0	38 0	26·40	3484	52·2	37·0
23 50	22·93	7260	40·0		39 0	27·60	2260		
24 0	23·03	7150			39 20	....	....	54·0	42·1
25 0	23·35	6810	42·0		3 6 0	....	on the ground	57·2	48·8
26 0	23·47	6640							

The reading of Regnault's hygrometer at $1^{h}\ 45^{m}$ was reduced to −30°, without any deposition of moisture; the temperature of the dew-point was therefore at a lower degree. At $1^{h}\ 48^{m}$ the temperature of the dew-point, as determined by the Dry- and Wet-bulb thermometers, was −35°, as shown below.

At $1^{h}\ 37^{m}$ the readings of the Dry and Wet thermometers (aspirated) were 15°·5 and 11°·3, giving a dew-point temperature of −21°·1.

At $1^{h}\ 37^{m}\ 10^{s}$ the readings of the Dry and Wet thermometers (free) were 15°·0 and 11°·1, giving a dew-point temperature of −18°·1.

At $1^{h}\ 37^{m}\ 50^{s}$ the readings of the Dry and Wet thermometers (free) were 14°·5 and 10°·2, giving a dew-point temperature of −13°·0.

At $1^{h}\ 38^{m}$ the readings of the Dry and Wet thermometers (aspirated) were 14°·2 and 10°·5, giving a dew-point temperature of −18°·1.

At $1^{h}\ 38^{m}\ 10^{s}$ the readings of the Dry and Wet thermometers (free) were 13°·2 and 10°·0, giving a dew-point temperature of −14°·8.

At $1^{h}\ 39^{m}$ the readings of the Dry and Wet thermometers (free) were 8°·0 and 4°·5, giving a dew-point temperature of −22°·7.

At $1^{h}\ 40^{m}\ 15^{s}$ the readings of the Dry and Wet thermometers (free) were 10°·2 and 8°·1, giving a dew-point temperature of −8°·2.

At $1^{h}\ 40^{m}\ 30^{s}$ the readings of the Dry and Wet thermometers (aspirated) were 9°·5 and 7°·8, giving a dew-point temperature of −5°·3.

At $1^{h}\ 44^{m}$ the readings of the Dry and Wet thermometers (free) were 8°·1 and 4°·2, giving a dew-point temperature of −26°·0.

At $1^{h}\ 45^{m}$ the readings of the Dry and Wet thermometers (aspirated) were 7°·3 and 4°·5, giving a dew-point temperature of −17°·3.

At $1^{h}\ 48^{m}$ the readings of the Dry and Wet thermometers (free) were 0°·0 and −4°·0, giving a dew-point temperature of −35°·2.

At $2^{h}\ 9^{m}$ the readings of the Dry and Wet thermometers (free) were 17°·0 and 11°·0, giving a dew-point temperature of −34°·7.

At $2^{h}\ 10^{m}$ the readings of the Dry and Wet thermometers (free) were 22°·5 and 15°·8, giving a dew-point temperature of −27°·0.

From the general agreement of the results as observed by Regnault's hygrometer and those of the dew-point as found by the Dry- and Wet-bulb thermometers, there can be no doubt that the temperature of the dew-point at heights exceeding 30,000 feet must have been as low as −50°.

Eighth Ascent.—September 8.

Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.	Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.
h m s	in.	feet.	°	°	h m s	in.	feet.	°	°
4 47 0	29·92	250	67·2	61·2	5 24 30	25·09	5039	51·5	44·9
48 0	29·47	813	66·5	60·4	25 0	25·30	4829	51·2	45·7
49 0	28·90	1232	63·2	58·2	25 30	25·50	4629	51·2	47·7
50 0	28·70	1530	63·1	57·8	26 0	25·92	4137	51·2	48·4
50 30	28·50	1730	62·8	57·2	26 20	26·69	3328	52·0	47·0
51 0	27·75	2432	60·2	54·6	27 0	26·80	3218	52·2	46·8
52 0	27·55	2520	58·8	54·4	27 30	....	3618	52·5	46·5
52 30	27·20	2923	56·5	52·1	28 0	....	3438	53·5	49·5
53 0	26·70	3320	55·2	49·9	29 30	27·06	2954	54·5	45·5
54 0	26·30	3720	54·0	48·5	30 30	27·25	2783	55·0	50·1
54 30	25·90	4169	52·0	49·0	31 0	27·52	2540	55·5	51·2
55 0	25·68	4380	51·5	49·5	31 30	27·60	2432	55·5	53·0
56 0	25·50	4560	51·0	48·6	31 45	27·68	2360	56·0	53·7
56 30	25·41	4650	50·5	49·1	32 0	27·82	2207	56·2	54·1
57 0	25·38	4727	50·5	49·5	32 30	27·95	2090	56·2	54·1
57 30	25·38	4727	50·8	48·8	33 0	28·05	1990	56·8	54·3
58 20	25·36	4750	51·1	48·6	33 15	28·17	1870	57·2	54·7
58 40	25·36	4750	50·5	49·1	33 30	28·30	1720	57·2	54·9
59 0	25·42	4690	50·3	48·0	34 0	28·40	1620	57·2	55·3
59 30	25·50	4610	49·5	47·9	35 0	28·49	1530	57·2	55·8
59 45	25·55	4560	49·3	47·7	35 30	28·60	1420	58·5	56·6
5 0 0	25·60	4510	49·5	46·8	36 0	28·65	1370	58·5	56·6
1 0	25·73	4480	50·0	45·9	36 20				
2 0	25·95	4160	49·8	48·2	37 0	28·80	1220	59·0	58·0
3 0	26·10	3946	50·5	49·1	37 30	28·95	1077	59·8	56·5
4 0	26·20	3850	50·8	48·9	38 30	29·10	932	60·0	59·6
4 30	26·28	3770	51·2	48·8	39 0	29·20	842	60·2	59·5
5 0	26·38	3670	51·5	50·1	39 15	29·25	805	60·5	58·6
5 30	26·70	3350	52·2	50·0	39 30	29·30	768	60·5	59·2
6 0	26·74	3310	52·5	50·5	40 0	29·28	782	61·0	60·1
6 30	26·78	3270	53·0	50·0	40 30	29·20	842	61·5	60·6
7 0	26·68	3370	53·5	49·5	41 0	29·18	856	61·1	61·0
7 30	26·25	3808	53·5	49·6	42 0	29·15	887	61·1	59·9
10 0	26·10	3958	52·5	50·5	43 0	29·15	887	61·1	59·9
10 30	25·95	4108	52·2	50·8	44 0	29·15	887	61·1	59·9
11 0	25·74	4220	51·5	48·5	44 30	29·20	842	61·1	59·0
11 30	25·52	4440	51·0	48·8	45 0	29·21	827	61·5	58·7
12 0	25·40	4540	51·0	40·8	45 30	....	805	61·7	58·5
12 15	25·22	4895	51·0	36·9	46 0	....	842	62·0	58·3
12 30	25·20	4920	51·1	37·0	47 0	29·18	856	61·5	58·7
13 0	25·20	4920	51·1	35·4	48 0	29·15	887	61·5	58·7
14 0	25·20	4920	53·2	34·9	48 30	29·15	887	61·2	58·6
15 0	25·19	4930	54·2	34·2	49 0	29·14	896	61·2	58·9
15 30	25·11	4926	55·2	33·5	49 10	29·18	856	61·2	58·6
16 0	25·00	5175	56·5	34·5	50 0	29·18	856	61·1	59·0
17 0	24·92	5263	57·2	35·9	50 30	29·21	826	61·1	58·6
17 30	24·95	5230	57·2	38·0	51 0	29·28	772	61·1	58·6
18 30	24·78	5428	58·5	40·5	52 0	29·38	672	61·5	58·7
19 0	24·82	5388	60·0	40·3	54 0	29·50	553	61·5	58·7
20 30	25·05	5112	58·2		54 30	29·54	517	62·0	59·2
21 0	25·05	5109	57·5	35·9	54 45	29·46	589	62·0	59·2
21 10	25·02	5145	57·5	35·9	55 0	29·12	895	62·2	59·0
21 20	25·00	5169	57·5	35·9	55 10	29·00	1040	62·2	59·0
22 0	25·08	5057	56·2	38·4	56 0	28·90	1130	61·8	58·5
22 40	25·09	5043	54·2	41·6	56 10	....	(1230)	61·5	58·2
23 50	25·10	5029	51·8	44·2	56 40	28·50	1520	61·1	57·0
24 0	25·11	5019	51·5	44·9	57 0	28·40	1628	60·8	56·0

EIGHTH ASCENT.—September 8 (*continued*).

Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.	Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Dew-point.
h m s	in.	feet.	°	°	h m s	in.	feet.	°	°
5 57 30	28·38	1639	60·5	55·8	6 1 30	27·98	2034	59·8	54·9
58 0	28·22	1798	60·0	56·2	1 45	27·90	2114	59·8	54·8
58 40	28·11	(1870)	60·0	56·6	2 0	27·90	2114	59·8	54·9
6 0 0	28·05	1967	60·5	56·0	3 40	27·78	2235	59·5	50·0
0 20	27·98	2034	60·0	57·1	5 0	27·89	2122	59·2	55·9
1 0	27·98	2034	60·0	55·8	10 0	30·07	on the ground		

UNIVERSITY CALIFORNIA

§ 5. VARIATION OF TEMPERATURE OF THE AIR WITH HEIGHT.

In order to arrive at an approximate value of the normal variation of temperature on each day, it is necessary to make some estimate of the amount of the disturbing causes.

For this purpose I placed every reading of temperature in the preceding Tables in the high ascents, or the means of small groups of observations in the low ascents, on diagrams, and joined all the points, and caused a curve to pass through or near them, so that every change of temperature was thus made evident to the eye.

In all these projected curves there were parts of evidently the same curve showing a gradual decrease of temperature with increase of elevation, and a gradual increase with decrease of elevation. These parts were connected and assumed to be a close approximation to the truth, and capable of giving approximate values of the normal variation of temperature with height. The departure in the projected curve of observed temperatures from the assumed curve of normal temperatures in these diagrams indicated the places and the amounts of disturbance. The next step was the reading from these curves the temperature at every thousand feet, and in this way the next Tables were formed. The numbers in the first column show the height in feet, beginning at 0 feet and increasing upwards; the numbers in the second column show the interval of time in ascending to the highest point; the notes in the third column show the circumstances of the observations; the numbers in the fourth and fifth columns the observations and the approximate normal temperature of the air; and those in the next column the difference between the two preceding columns, or the most probable effect of the presence of cloud or mist on the temperature, or of other disturbing causes in operation.

The next group of columns are arranged similarly for the descent, and the other groups for succeeding ascents and descents.

TABLE III.—Showing the Temperature of the Air, as read off the curve drawn through the observed temperatures, and as read off the curve of most probable normal temperature, called adopted temperature, and the calculated amount of disturbance from the assumed law of decrease of temperature.

Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
July 17.			°	°	°			°	°	°
26000	From 9h 43m a.m. to 11h 1m a.m.	Above cloud.	16·0	16·0	0·0	From 11h 2m a.m. to 11h 50m a.m.	Above cloud.	16·0	16·0	0·0
25000			16·0	16·0	0·0			18·0	17·2	+ 0·8
24000			16·8	16·0	+ 0·8			26·0	18·5	7·5
23000			17·9	16·1	1·8			27·9	19·8	8·1
22000			19·5	16·2	3·3			28·1	21·0	7·1
21000			24·1	16·8	7·3			28·5	22·5	6·0
20000			32·1	17·0	15·1			28·6	23·9	4·7
19000			39·5	17·3	22·2			28·8	25·0	3·8
18000			35·2	17·8	17·4			29·0	26·2	2·8
17000			32·7	18·0	14·7			29·2	27·8	1·4
16000			31·9	18·5	13·4			29·5	29·0	+ 0·5
15000			31·2	19·5	12·7			30·5	30·5	0·0
14000			29·5	20·1	9·4			31·5	31·5	0·0
13000			26·7	21·5	5·2			33·0	33·0	0·0
12000			25·9	22·3	3·6		In cloud.	34·5	34·5	0·0
11000			26·0	24·0	2·0			36·0	36·0	0·0
10000			26·2	26·0	0·2			37·5	37·5	0·0
9000			29·0	29·0	0·0					
8000		In cloud.	32·0	32·0	0·0					
7000			36·5	36·5	0·0					
6000			34·8	41·0	6·2					
5000			39·3	45·2	5·9					
4000		Under cloud.	43·5	50·0	6·5					
3000			47·9	54·8	9·1					
2000			52·5	59·8	7·3					
1000			56·9	64·1	7·2					
0			61·5	70·0	+ 8·5					

July 17.—The departure in this ascent from a regular progression is very remarkable. Below the cloud the decrease of temperature was pretty well uniform; on passing out of it there was an increase of 6°, and then the decrease was resumed. At 10,000 feet the temperature was 26°, and there was no change in the next 3000 feet; then a very remarkable increase took place, till at 19,500 feet with a temperature of 42° the rise was checked, and then declined rapidly to 16° at 5 miles high. In the descent a disturbance from the regular increase of temperature was met with at the height of 24,000 feet, and continued to 17,000 feet; at 13,000 feet clouds were reached, and no observations were taken below 10,000 feet.

The dense clouds which covered the earth caused an apparent loss of temperature of about 8½°; and the effect of a warm current of air, which was first met with at the height of 11,000 feet, amounted, at 19,500 feet, to fully 25° warmer than would have been had this intermediate current of warm air not existed. The excess of warmth is shown at the different elevations of 1000 feet in the 6th column of the Table for this day.

TABLE III. (*continued.*)

Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
July 30.			°	°	°			°	°	°
7000	From $4^h\ 36^m$ to $5^h\ 43^m$ p.m.	Misty.	..	42·8	..	From $5^h\ 44^m$ to $6^h\ 30^m$ p.m.	..	44·0	44·0	0·0
6000			43·5	45·5	− 2·0		..	46·0	46·0	0·0
5000			48·2	48·2	0·0		..	47·4	47·4	0·0
4000			52·0	50·8	+ 1·2		..	49·2	49·2	0·0
3000			52·7	53·2	− 0·5		..	54·1	54·1	0·0
2000			59·5	57·0	+ 2·5		..	59·2	59·2	0·0
1000			62·9	62·9	0·0		..	63·2	63·2	0·0
0			70·7	70·7	0·0		..	68·0	68·0	0·0
August 18.										
12000	From $1^h\ 2^m$ to $1^h\ 21^m$ p.m.	The cumulus cloud extended only from 3000 to 4000 feet.	..	..	..	From $1^h\ 22^m$ to $1^h\ 48^m$ p.m.	..	..	..	..
11000			39·2	38·0	+ 1·2		..	41·2	38·0	+ 3·2
10000			41·8	39·5	2·3		..	44·5	40·0	4·5
9000			44·0	40·8	3·2		..	46·5	46·8	4·7
8000			45·2	42·0	3·2		..	50·0	44·0	6·0
7000			46·1	43·8	2·3		..	54·0	46·0	4·0
6000			47·2	45·0	2·2		..	53·5	48·0	5·5
5000			48·5	46·5	2·0		..	52·7	51·0	1·7
4000			49·9	49·2	+ 0·7		..	54·1	53·5	+ 0·6
3000			52·8	52·8	0·0		..	56·0	56·0	0·0
2000			57·5	57·5	0·0		..			
1000			62·9	62·9	0·0		..			
0			70·9	70·9	0·0		..			

On descending, a warm current of air was entered at the height of 24,000 feet, and extended downwards to 16,000 or 17,000 feet, and the calculated effect of this is shown in the 11th or last column on July 17, on the opposite page.

July 30.—There were alternately warm and cold currents at different elevations, as the balloon passed down the valley of the Thames; the departure from the curved line which was made to pass through the observed readings when laid on a large diagram, at times was from 1° to 3° in excess, and at other times nearly as much in defect; but in the descent, which was rather rapid, there were no disturbing causes in operation. The amounts of disturbance in the ascent will be seen at each 1000 feet in the preceding Table.

On August 18 the temperature of the air decreased as usual on leaving the earth, until at the height of 4000 feet the rapidity of the decrease was arrested, and a warm current of air met with, which continued till the height of 11,500 feet was reached, when the balloon turned to descend, when the same warm current was passed, extending to the same limits; and was met with again on the re-ascension, at about the same distance from the earth, and found to extend to the height of 14,000 feet, when the regular diminution was resumed, and afterwards continued to the highest point reached: on the second descent, the same warm current of air was again met with, and continued till clouds were reached at the height of 6500 feet, which caused another interruption in the regular increase of temperature, as is usual in entering cloud from above. The temperatures of the air at every 1000 feet, as observed, were

TABLE III. (*continued.*)

Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
August 18.			°	°	°			°	°	°
23000	From 1^{h} 48^{m} to 2^{h} 59^{m} p.m.	..	24·0	24·0	0·0	From 3^{h} 0^{m} to 4^{h} 6^{m} p.m.	Above cloud.	24·0	24·0	0·0
22000		..	24·2	24·2	0·0			24·4	24·4	0·0
21000		..	24·4	24·4	0·0			25·2	25·2	0·0
20000		..	24·6	24·6	0·0			26·0	26·0	0·0
19000		..	25·7	25·0	+ 0·7			27·0	27·0	0·0
18000		..	31·0	26·0	+ 5·0			28·0	28·0	0·0
17000		..	27·2	27·2	0·0			29·0	29·0	0·0
16000		..	28·8	28·8	0·0			30·0	30·0	0·0
15000		..	30·8	30·8	0·0			31·0	31·0	0·0
14000		..	33·5	32·8	+ 0·7			32·2	32·2	0·0
13000		..	37·5	34·9	2·6			34·0	34·0	0·0
12000		..	40·5	37·0	3·5			38·5	36·5	+ 2·0
11000		..	45·0	38·9	6·1			40·0	39·2	0·8
10000		..	49·5	41·0	8·5			46·0	42·0	4·0
9000		..	50·7	43·2	7·5			48·2	44·8	3·4
8000		..	51·0	45·2	5·8			50·0	47·2	2·8
7000		..	52·8	47·8	5·0			51·0	50·5	+ 0·5
6000		..	54·7	49·8	+ 4·9			53·8	53·8	0·0
5000		..	52·0	52·0	0·0		In cloud.	56·0	56·0	0·0
4000		..	54·1	54·1	0·0			53·2	62·0	− 8·8
3000		..	56·0	56·0	0·0		Below cloud.	57·2	66·5	9·3
2000		..						61·0	71·6	5·6
1000		.						64·8	76·5	11·7
0								69·0	83·0	−14·0
August 20.										
5000	From 6^{h} 26^{m} to 6^{h} 47^{m} p.m.	In cloud.	..	..	..	From 6^{h} 49^{m} to 7^{h} 20^{m} p.m.	In cloud.			
4000		Under cloud.	49·8	49·8	0·0			48·8	48·8	0·0
3000			53·8	53·8	0·0		Under cloud.	51·6	51·6	0·0
2000			58·0	58·0	0·0			54·6	54·6	0·0
1000		..	62·5	62·5	0·0		..	57·6	57·6	
0		..	67·4	67·4	0·0					
5000	From 7^{h} 21^{m} to 8^{h} 5^{m} p.m.	In cloud.	45·6	45·6	0·0					
4000			49·2	49·2	0·0					
3000			53·2	53·2	0·0					
2000			56·8	56·8	0·0					
1000			57·6	57·6	0·0					
0										

laid down on a diagram, from which the values of the temperature at every 1000 feet, as shown in the preceding Table, with the approximate amount of the disturbance caused by the warm currents of air, were read.

August 20.—The clouds were not passed; at heights above 3500 feet the balloon ascended and descended repeatedly. In this ascent there was no marked interruption to the regular decrease of temperature with increase of height.

TABLE III. (*continued.*)

Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
August 21.			°	°	°			°	°	°
14000	From $4^h\ 30^m$ to $5^h\ 51^m$ a.m.	Above cloud.	22·7	22·7	0·0	From $5^h\ 52^m$ to $7^h\ 10^m$ a.m.	Above cloud.	23·7	23·7	0·0
13000			24·0	24·0	0·0			26·0	26·0	0·0
12000			26·2	26·2	0·0			29·2	29·2	0·0
11000			29·0	29·0	0·0			32·1	32·1	0·0
10000			31·8	31·8	0·0			35·6	35·6	0·0
9000			34·3	34·3	0·0			39·1	39·1	0·0
8000			37·4	37·4	0·0			42·9	42·9	0·0
7000			41·2	41·2	0·0		In cloud.	46·5	46·5	0·0
6000		In cloud.	40·0	45·0	− 5·0			40·5	50·0	− 9·5
5000			43·5	49·0	5·5		Below cloud.	43·5	54·0	10·5
4000		Below cloud.	47·2	53·0	5·8			47·0	58·0	11·0
3000			51·0	57·1	6·3			50·1	62·6	12·5
2000			54·5	61·7	7·2			54·0	67·6	13·6
1000			58·0	66·0	8·0			58·0	73·6	15·6
0		. . .	61·8	70·0	− 8·2			62·0	79·0	−17·0
September 1.										
4000	From $4^h\ 52^m$ to $5^h\ 35^m$ p.m.	...	47·5	47·5	0·0	From $5^h\ 36^m$ to $6^h\ 2^m$ p.m.	..	46·5	46·5	0·0
3000		...	50·7	50·7	0·0		..	48·5	48·5	0·0
2000		...	54·5	54·5	0·0		..	51·5	51·5	0·0
1000		...	59·2	59·2	0·0					
0		...	65·7	65·7	0·0					
4000	From $6^h\ 3^m$ to $6^h\ 6^m$ p.m.	Clouds above and below. Rain falling from the latter on the earth.					Clouds above and below. Rain falling on balloon.			
3000			53·5	53·5	0·0			53·5	53·5	0·0
2000			54·0	54·0	0·0					
1000										
0										

August 21.—The sky was cloudy, and the decrease of temperature was nearly uniform till the clouds were reached; on passing through them the usual increase of temperature took place to the amount of about 5°; then there was no particular interruption till the height of nearly 3 miles was passed; at this elevation the balloon continued for half an hour, during which time the temperature increased 3 or 4 degrees. In the descent no marked interruption was experienced from a regular increase of temperature till the clouds were entered; on passing through them a decrease of temperature of 10° was experienced, and after this the regular increase was resumed—the same temperatures being met with at the same elevations as in the ascent. The increase of temperature therefore experienced above the clouds, as the sun rose, had not penetrated in the least degree below the clouds; therefore the effect of the presence of cloud in the descent was much larger than in the ascent, as will be seen in the Table.

September 1.—The sky was covered with cirrostratus clouds which were never reached; there was no marked interruption in the regular decrease of temperature either in the ascent or descent; at the time of the second ascent the balloon was situated between two layers of clouds, and rain was falling upon it, which had the effect of equalizing the temperature, as no change of temperature took place in ascending from 1000 feet to 3000 feet. The curves

TABLE III. (*continued.*)

Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
September 5.			°	°	°			°	°	°
29000	From 1h 3m to 1h 53m p.m.	Above cloud.	− 5·3	− 5·3	0·0	From 2h 7m to 3h 6m p.m.				
28000			− 4·5	− 4·5	0·0					
27000			− 3·6	− 3·6	0·0					
26000			− 2·6	− 2·6	0·0					
25000			− 1·6	− 1·6	0·0		..	− 2·0	− 2·0	0·0
24000			0·0	− 0·5	+ 0·5		..	− 0·9	− 0·9	0·0
23000			+ 2·2	+ 1·0	+ 1·2		..	+ 1·2	+ 1·2	0·0
22000			4·6	2·5	2·1		..	8·0	3·3	+ 4·7
21000			7·2	4·5	2·7		..	14·0	5·5	8·5
20000			10·0	6·5	3·5		..	16·8	7·7	9·1
19000			15·0	9·0	6·0		..	17·5	10·0	7·5
18000			15·5	11·5	4·0		..	17·8	12·0	5·8
17000			16·8	14·0	2·8		..	17·8	14·8	3·0
16000			17·5	16·5	+ 1·0		..	18·0	17·5	+ 0·5
15000			19·5	19·5	0·0		..	20·0	20·0	0·0
14000			22·0	22·0	0·0		..	22·5	22·5	0·0
13000			24·5	24·5	0·0		..	25·0	25·0	0·0
12000			27·0	27·0	0·0		..	27·8	27·8	0·0
11000			29·8	29·8	0·0		..	30·5	30·5	0·0
10000			32·2	32·2	0·0		..	33·0	33·0	0·0
9000			35·0	35·0	0·0		..	36·1	36·1	0·0
8000			38·5	38·5	0·0		..	38·7	38·7	0·0
7000			33·9	42·0	− 8·1		..	41·4	41·4	0·0
6000		Below cloud.	37·0	46·0	9·0		..	44·5	44·5	0·0
5000			40·8	50·0	9·2		..	47·2	47·2	0·0
4000			44·8	54·5	9·7		..	50·0	50·0	0·0
3000			48·9	60·0	11·1		..	53·0	53·0	0·0
2000			53·0	65·0	12·0		..	56·0	56·0	0·0
1000			57·5	70·0	12·5		..	59·2	59·2	0·0
0			62·0	77·2	−15·2		..	62·6	62·6	0·0

of observed and adopted temperatures were laid down on a diagram, and the temperatures at each 1000 feet as taken from the diagram are inserted in the preceding Tables.

September 5.—In this ascent on passing out of the clouds there was an increase of 9°, and then there was no interruption in the decrease of temperature till the height of 15,500 feet was reached, when a warm current of air was entered and continued to 24,000 feet, after which the regular decrease of temperature continued to the highest point reached. On descending, the same warm current was again met with between 22,000 and 23,000 feet, and a similar interruption, but to a greater amount, was experienced till the balloon had descended to about the same height as it was reached on ascending; after this there was no further interruption in the regular increase of temperature, the sky being clear till the descent was completed. An inspection of the Table will show the locality and extent of the warm current of air and the temperature at every 1000 feet both in the ascent and descent, with the probable amount of the increase of temperature caused by the warm stratum of air, and also the probable amount of loss of heat under the clouds caused by their presence.

TABLE III. (*continued*).

Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
September 8.			°	°	°			°	°	°
5000	From 4^h 47^m to 4^h 58^m p.m.	Above cloud.	50·0	50·0	0·0	From 5^h 0^m to 5^h 9^m p.m.	Above cloud.	..	51·1	
4000			52·7	52·7	0·0			..	50·3	
3000		In cloud	56·4	56·4	0·0		In cloud			
2000			61·0	61·0	0·0					
1000		Below cloud.	65·1	65·1	0·0					
0			69·0	69·0	0·0					
5000	From 5^h 10^m to 5^h 18^m p.m.	..	..	55·3	..	From 5^h 19^m to 6^h 10^m p.m.	..	..	51·4	
4000		..	..	52·5	..		..	..	51·2	
3000		..	..	..	..		..	..	53·9	
2000		..	..	..	..		..	..	56·5	
1000		..	..	..	..		..	..	60·2	
0		..	..	..	..		..	..	64·8	

September 8.—The sky was cloudy, and the decrease of temperature was nearly uniform, and there was no marked interruption in the regular decrease of temperature on descending.

The next Table has been formed by taking the difference between consecutive numbers in the preceding Tables, in each of the several ascents. The disturbances on July 17 were so great and the results so different from those on the other days of experiments, that no use has been made of the results, other than inserting them in the Table.

Table IV.—Showing the Decrease of Temperature

Height above the level of the sea.		July 17.		July 30.		August 18.				August 20.		
		State of the Sky.										
		Cloudy.		Clear.	Cloudy.	Clear.				Cloudy.		
From	To	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.
ft.	ft.	o	o	o	o	o	o	o	o	o	o	o
28000	29000	...	...	...	...	...	...	...	...	...	...	...
27000	28000	...	...	...	...	...	...	...	...	...	...	...
26000	27000	...	...	...	...	...	...	...	...	...	...	...
25000	26000	0·0	1·2	...	...	...	...	...	...	...	...	...
24000	25000	0·0	1·3	...	...	...	...	...	...	...	...	...
23000	24000	0·1	1·3	...	...	...	...	...	...	...	...	...
22000	23000	0·1	1·2	...	...	...	...	0·2	0·4	...	...	...
21000	22000	0·6	1·5	...	...	...	...	0·2	0·8	...	...	...
20000	21000	0·2	1·4	...	...	...	...	0·2	0·8	...	...	...
19000	20000	0·3	1·1	...	...	...	...	0·4	1·0	...	...	...
18000	19000	0·5	1·2	...	...	...	...	1·0	1·0	...	...	...
17000	18000	0·2	1·6	...	...	...	...	1·2	1·0	...	...	...
16000	17000	0·5	1·2	...	...	...	...	1·6	1·0	...	...	...
15000	16000	1·0	1·5	...	...	...	...	2·0	1·0	...	...	...
14000	15000	0·6	1·0	...	...	...	...	2·0	1·2	...	...	...
13000	14000	1·4	1·5	...	...	...	...	2·1	1·8	...	...	...
12000	13000	0·8	1·5	...	...	...	...	2·1	2·5	...	...	...
11000	12000	1·7	1·5	...	...	...	...	1·9	2·7	...	...	...
10000	11000	2·0	1·5	...	...	1·5	2·0	2·1	2·8	...	...	...
9000	10000	3·0	...	...	...	1·3	1·8	2·2	2·8	...	...	...
8000	9000	3·0	...	...	...	1·2	2·2	2·0	2·4	...	...	...
7000	8000	4·5	...	...	...	1·8	2·0	2·6	3·3	...	...	...
6000	7000	4·5	...	2·7	2·0	1·2	2·0	3·0	3·3	...	...	...
5000	6000	4·2	...	2·7	1·4	1·5	3·0	2·2	4·0	...	...	
4000	5000	4·8	...	2·6	1·8	2·7	2·5	2·1	4·0	...	...	
3000	4000	4·8	...	2·4	4·9	3·6	2·5	1·9	4·5	4·0	2·8	
2000	3000	5·0	...	3·8	5·1	4·7	...	...	5·1	5·0	3·0	
1000	2000	4·3	...	5·9	4·0	5·4	...	...	4·9	4·5	...	
0	1000	5·9	...	7·8	4·8	8·0	...	...	6·5	4·9	...	

A glance at this Table shows that, without exception, the numbers at the lower elevations are very much larger, in all states of the sky, than those at the higher, and therefore that the changes of temperature are much larger near the earth, for equal increment of elevation, than far from it.

Also by comparing the numbers at low elevations with cloudy and clear skies, those with the former are much smaller than those with the latter, and therefore the decrease of temperature with increase of elevation is larger with a clear than with a cloudy sky.

By taking the mean of the results at every stratum of 1000 feet, omitting those belonging to July 17, we have—

TABLE III. (*continued*).

Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
September 8.			°	°	°			°	°	°
5000	From 4h 47m to 4h 58m p.m.	Above cloud.	50·0	50·0	0·0	From 5h 0m to 5h 9m p.m.	Above cloud.	..	51·1	
4000			52·7	52·7	0·0			..	50·3	
3000		In cloud	56·4	56·4	0·0		In cloud			
2000			61·0	61·0	0·0					
1000		Below cloud.	65·1	65·1	0·0					
0			69·0	69·0	0·0					
5000	From 5h 10m to 5h 18m p.m.	..	..	55·3	..	From 5h 19m to 6h 10m p.m.	..	..	51·4	
4000		..	..	52·5	..		..	..	51·2	
3000		..	..	..	..		..	..	53·9	
2000		..	..	..	..		..	..	56·5	
1000		..	..	..	..		..	..	60·2	
0		..	..	..	..		..	..	64·8	

September 8.—The sky was cloudy, and the decrease of temperature was nearly uniform, and there was no marked interruption in the regular decrease of temperature on descending.

The next Table has been formed by taking the difference between consecutive numbers in the preceding Tables, in each of the several ascents. The disturbances on July 17 were so great and the results so different from those on the other days of experiments, that no use has been made of the results, other than inserting them in the Table.

These results differ considerably from those found in a cloudy sky, and doubtless the difference between experiments carried on under a cloudless sky at these elevations would differ still more. They do not at all confirm the law of gradation of temperature of 1° in 300 feet.

THE DECREASE OF THE TEMPERATURE OF THE AIR

At heights exceeding 5000 *feet.*

	feet.		feet.		°					°		
From	5,000	to	6,000	was	2·8	from	10	experiments,	or	1 in	357	feet.
„	6,000	„	7,000	„	2·8	„	8	„	„	„	357	„
„	7,000	„	8,000	„	2·7	„	8	„	„	„	370	„
„	8,000	„	9,000	„	2·6	„	8	„	„	„	384	„
„	9,000	„	10,000	„	2·6	„	8	„	„	„	384	„
„	10,000	„	11,000	„	2·6	„	8	„	„	„	384	„
„	11,000	„	12,000	„	2·6	„	6	„	„	„	384	„
„	12,000	„	13,000	„	2·5	„	6	„	„	„	400	„
„	13,000	„	14,000	„	2·2	„	6	„	„	„	455	„
„	14,000	„	15,000	„	2·1	„	4	„	„	„	477	„
„	15,000	„	16,000	„	2·1	„	4	„	„	„	477	„
„	16,000	„	17,000	„	1·9	„	4	„	„	„	527	„
„	17,000	„	18,000	„	1·8	„	4	„	„	„	556	„
„	18,000	„	19,000	„	1·8	„	4	„	„	„	556	„
„	19,000	„	20,000	„	1·5	„	4	„	„	„	667	„
„	20,000	„	21,000	„	1·3	„	4	„	„	„	771	„
„	21,000	„	22,000	„	1·3	„	4	„	„	„	771	„
„	22,000	„	23,000	„	1·0	„	4	„	„	„	1000	„
„	23,000	„	24,000	„	1·3	„	2	„	„	„	771	„
„	24,000	„	25,000	„	1·1	„	2	„	„	„	909	„
„	25,000	„	26,000	„	1·0	„	1	„	„	„	1000	„
„	26,000	„	27,000	„	1·0	„	1	„	„	„	1000	„
„	27,000	„	28,000	„	0·9	„	1	„	„	„	1111	„
„	28,000	„	29,000	„	0·8	„	1	„	„	„	1250	„

These results follow almost in sequence with those found with the partially clear sky, and together show that a change of temperature of 1° takes place in 139 feet near the earth, and that it requires fully 1000 feet, for a change of 1°, at the height of 30,000 feet; the intermediate heights require a gradually increasing space between these limits to its elevation, and plainly indicate that the theory of a decline of temperature of 1° for every 300 feet of ascent must be abandoned.

By adding successively together the decrease due to each 1000 feet, we have the whole decrease of temperature from the earth to the different elevations:—

ft.	feet.		°		feet.
From 0 to	1,000	the decrease was	7·2,	or 1° on the average of	139
„	2,000	„	12·5	„	160
„	3,000	„	17·1	„	176
„	4,000	„	20·5	„	195
„	5,000	„	23·2	„	211
„	6,000	„	26·0	„	230
„	7,000	„	28·8	„	243
„	8,000	„	31·5	„	254
„	9,000	„	34·1	„	263

in every 1000 feet of elevation up to 29,000 feet.

August 21.		September 1.		September 5.		September 8.		Mean (omitting July 17).			
State of the Sky.											
Cloudy.		Partially clear.	Cloudy.	Partially clear.	Cloudy.	Cloudy.		Cloudy.	Clear.	Clear.	Number of experiments.
Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	At heights less than 5000 feet.		At heights exceeding 5000 feet.	
0	0	0	0	0	0	0	0	0	0	0	
...	...	...	...	0·8	...	...	...	...	...	0·8	1
...	...	...	...	0·9	...	...	...	...	...	0·9	1
...	...	...	...	1·0	...	...	...	...	...	1·0	1
...	...	...	...	1·0	...	...	...	...	...	1·0	1
...	...	...	...	1·1	1·1	...	...	...	...	1·1	2
...	...	...	...	1·5	2·1	...	...	...	...	1·3	2
...	...	...	...	1·5	2·1	...	...	...	...	1·0	4
...	...	...	...	2·0	2·2	...	...	...	...	1·3	4
...	...	...	...	2·0	2·2	...	...	...	...	1·3	4
...	...	...	...	2·5	2·3	...	...	...	...	1·5	4
...	...	...	...	2·5	2·0	...	...	...	...	1·8	4
...	...	...	...	2·5	2·8	...	...	...	...	1·8	4
...	...	...	...	2·5	2·7	...	...	...	...	1·9	4
...	...	...	...	3·0	2·5	...	...	...	...	2·1	4
...	...	...	...	2·5	2·5	...	...	...	...	2·1	4
1·3	2·3	...	...	2·5	2·5	...	...	...	...	2·2	6
2·2	3·2	...	...	2·5	2·8	...	...	...	...	2·5	6
3·8	2·9	...	...	2·8	2·7	...	...	...	...	2·6	6
2·8	3·5	...	...	2·4	2·5	...	...	...	...	2·6	8
2·5	3·5	...	...	2·8	3·1	...	...	...	...	2·6	8
3·1	3·8	...	...	3·5	2·6	...	...	...	...	2·6	8
3·8	3·6	...	...	3·5	2·7	...	...	...	...	2·7	8
3·8	3·5	...	...	4·0	3·5	...	...	...	...	2·8	8
4·0	4·0	...	...	4·0	2·7	...	...	...	...	2·8	10
4·0	4·0	...	...	3·5	2·8	2·7	...	3·1	2·9	...	6 & 5
4·1	4·6	3·2	2·0	5·5	3·0	3·7	2·7	3·7	3·4	...	10 & 7
4·6	5·0	3·8	3·0	5·0	3·0	4·6	3·6	4·1	4·6	...	10 & 5
4·3	5·4	4·7	...	5·0	3·2	4·1	3·7	4·2	5·3	...	7 & 5
4·0	6·0	6·5	...	7·2	3·4	3·9	4·6	4·5	7·2	...	7 & 5

THE MEAN DECREASE OF TEMPERATURE OF THE AIR

When the Sky was Cloudy,

Up to 1000 feet was 4°·5 from 7 experiments, or 1° in 222 feet.
From 1000 to 2000 „ 4°·2 „ 7 „ „ „ 239 feet.
From 2000 to 3000 „ 4°·1 „ 10 „ „ „ 244 feet.
From 3000 to 4000 „ 3°·7 „ 10 „ „ „ 271 feet.
From 4000 to 5000 „ 3°·1 „ 6 „ „ „ 323 feet.

These results do not differ very greatly from the law of decrement of temperature, as found from observations on mountain-sides, viz. 1° in 300 feet.

When the Sky was partially Clear,

Up to 1000 feet was 7°·2 from 5 experiments, or 1° in 139 feet.
From 1000 to 2000 „ 5°·3 „ 5 „ „ „ 189 feet.
From 2000 to 3000 „ 4°·6 „ 5 „ „ „ 254 feet.
From 3000 to 4000 „ 3°·4 „ 7 „ „ „ 295 feet.
From 4000 to 5000 „ 2°·9 „ 6 „ „ „ 345 feet.

rature is distributed: for this purpose all the observations of the temperature of the air taken within this distance of the earth were laid down upon large diagrams; a curved line was made to pass through or near them, and the reading at every 100 feet was taken from these curves, and those at every even hundred were inserted in the following Tables, as well as those from the projected curves as found by joining the observations themselves, and in this way the following Tables were formed:—

TABLE V.—Showing the Mean Temperature of the Air at every 200 feet up to 5000 feet.

Height, in feet, above the mean level of the sea.	Temperature of the Air.				
	Ascending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
July 17.	From $9^h 43^m$ a.m. to $9^h 51^m$ a.m.		°	°	°
5000		In cloud.	39·3	39·3	0·0
4800			40·4	40·4	0·0
4600			41·4	41·4	0·0
4400			42·4	42·4	0·0
4200			43·4	43·4	0·0
4000		Under cloud.	44·5	44·5	0·0
3800			45·2	45·2	0·0
3600			46·0	46·0	0·0
3400			46·9	46·9	0·0
3200			47·8	47·8	0·0
3000			48·6	48·6	0·0
2800			49·4	49·4	0·0
2600			50·3	50·3	0·0
2400			51·0	51·0	0·0
2200			51·7	51·7	0·0
2000			52·5	52·5	0·0
1800			53·4	53·4	0·0
1600			54·3	54·3	0·0
1400			55·2	55·2	0·0
1200			56·0	56·0	0·0
1000			56·9	56·9	0·0
800			57·7	57·7	0·0
600			58·6	58·6	0·0
400			59·5	59·5	0·0
200			60·5	60·5	0·0
0			61·5	61·5	0·0

July 17.—The results are dependent upon the observations before leaving the earth, joined to those taken at and above 3800 feet; but they accord with others under the same state of the sky, indicating an almost uniformly decreasing temperature until the thick cloud was reached.

July 30.—The fluctuations on this day are better shown here than in the preceding section; there seem to have been no fewer than four or five different strata, on this day, within 7000 feet of the earth, experienced during the ascent and passage of the balloon till the time of descent, which was rapid, and during which the increase of temperature was gradual throughout.

TABLE V. (*continued.*)

Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
July 30.			°	°	°			°	°	°
5000	From 4^h 36^m p.m. to 5^h 11^m p.m.	Misty	48·2	48·2	0·0	From 6^h 21^m p.m. to 6^h 30^m p.m.	..	47·3	47·3	0·0
4800		..	48·2	48·8	− 0·6		..	47·6	47·6	0·0
4600		..	49·7	49·3	+ 0·4		..	47·9	47·9	0·0
4400		..	50·9	49·8	1·1		..	48·2	48·2	0·0
4200		..	51·7	50·3	1·4		..	48·6	48·6	0·0
4000		..	52·0	50·8	+ 1·2		..	49·2	49·2	0·0
3800		..	50·6	51·2	− 0·6		..	49·9	49·9	0·0
3600		..	50·7	51·7	1·0		..	50·9	50·9	0·0
3400		..	51·5	52·2	0·7		..	52·0	52·0	0·0
3200		..	52·2	52·8	0·6		..	53·0	53·0	0·0
3000		..	52·7	53·2	0·5		..	54·1	54·1	0·0
2800		..	53·2	53·8	0·6		..	55·2	55·2	0·0
2600		..	53·7	54·6	− 0·9		..	56·3	56·3	0·0
2400		..	57·0	55·3	+ 1·7		..	57·3	57·3	0·0
2200		..	59·0	56·0	3·0		..	58·2	58·2	0·0
2000		..	59·5	57·0	1·5		..	59·2	59·2	0·0
1800		..	60·0	58·1	1·9		..	60·0	60·0	0·0
1600		..	60·9	59·2	1·7		..	60·9	60·9	0·0
1400		..	61·9	60·2	1·7		..	61·5	61·5	0·0
1200		..	62·0	61·6	+ 0·4		..	62·2	62·2	0·0
1000		..	62·9	62·9	0·0		..	63·2	63·2	0·0
800		..	64·0	64·0	0·0		..	64·2	64·2	0·0
600		..	65·2	65·2	0·0		..	65·1	65·1	0·0
400		..	66·8	66·8	0·0		..	66·0	66·0	0·0
200		..	68·6	68·6	0·0		..	67·0	67·0	0·0
0		..	70·7	70·7	0·0		..	68·0	68·0	0·0
August 18.										
5000	From 0^h 53^m p.m. to 1^h 11^m p.m.	Above cloud.	48·5	48·5	0·0	From 3^h 50^m p.m. to 4^h 5^m p.m.	In cloud.	49·5	49·5	0·0
4800			48·8	48·8	0·0			50·2	50·2	0·0
4600			49·0	49·0	0·0			51·0	51·0	0·0
4400			49·2	49·2	0·0			51·8	51·8	0·0
4200			49·5	49·5	0·0			52·5	52·5	0·0
4000		In a cumulus cloud.	49·9	49·9	0·0		Below cloud.	53·2	53·2	0·0
3800			50·4	50·4	0·0			54·0	54·0	0·0
3600			50·9	50·9	0·0			54·9	54·9	0·0
3400			51·5	51·5	0·0			55·7	55·7	0·0
3200			52·2	52·2	0·0			56·5	56·5	0·0
3000		Below cloud.	53·0	53·0	0·0			57·2	57·2	0·0
2800			53·7	53·7	0·0			57·9	57·9	0·0
2600			54·6	54·6	0·0			58·7	58·7	0·0
2400			55·6	55·6	0·0			59·4	59·4	0·0
2200			56·6	56·6	0·0			60·2	60·2	0·0
2000			57·5	57·5	0·0			61·0	61·0	0·0
1800			58·4	58·4	0·0			61·7	61·7	0·0
1600			59·5	59·5	0·0			62·4	62·4	0·0
1400			60·4	60·4	0·0			63·1	63·1	0·0
1200			61·7	61·7	0·0			64·0	64·0	0·0
1000			62·9	62·9	0·0			64·8	64·8	0·0
800			64·4	64·4	0·0			65·7	65·7	0·0
600			66·0	66·0	0·0			66·5	66·5	0·0
400			67·6	67·6	0·0			67·3	67·3	0·0
200			69·2	69·2	0·0			68·1	68·1	0·0
0			70·9	70·9	0·0			69·0	69·0	0·0

TABLE V. (*continued.*)

Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
August 20.			°	°	°			°	°	°
4200	From 6h 5m p.m. to 6h 47m p.m.	Below cloud.	48·8	48·8	0·0	From 6h 47m p.m. to 7h 20m p.m.	Below cloud.	48·4	48·4	0·0
4000			49·8	49·8	0·0			48·8	48·8	0·0
3800			50·8	50·8	0·0			49·1	49·1	0·0
3600			51·6	51·6	0·0			49·6	49·6	0·0
3400			52·3	52·3	0·0			50·2	50·2	0·0
3200			53·0	53·0	0·0			50·9	50·9	0·0
3000			53·8	53·8	0·0			51·6	51·6	0·0
2800			54·7	54·7	0·0			52·2	52·2	0·0
2600			55·4	55·4	0·0			52·9	52·9	0·0
2400			56·1	56·1	0·0			53·3	53·3	0·0
2200			57·1	57·1	0·0			54·0	54·0	0·0
2000			58·0	58·0	0·0			54·6	54·6	0·0
1800			59·0	58·0	0·0			55·2	55·2	0·0
1600			59·9	59·9	0·0			55·8	55·8	0·0
1400			60·8	60·8	0·0			56·5	56·5	0·0
1200			61·7	61·7	0·0					
1000			62·5	62·5	0·0					
800			63·4	63·4	0·0					
600			64·3	64·3	0·0					
400			65·2	65·2	0·0					
200			66·3	66·3	0·0					
0			67·4	67·4	0·0					
5000	From 7h 20m p.m. to 7h 47m p.m.	In cloud.	45·6	45·6	0·0					
4800			46·2	46·2	0·0					
4600		Below cloud.	47·0	47·0	0·0					
4400			47·9	47·9	0·0					
4200			48·5	48·5	0·0					
4000			49·2	49·2	0·0					
3800			50·0	50·0	0·0					
3600			50·8	50·8	0·0					
3400			51·7	51·7	0·0					
3200			52·4	52·4	0·0					
3000			53·1	53·1	0·0					
2800			54·0	54·0	0·0					
2600			54·8	54·8	0·0					
2400			55·4	55·4	0·0					
2200			56·1	56·1	0·0					
2000			56·8	56·8	0·0					
1800			57·4	57·4	0·0					
1600			58·0	58·0	0·0					
1400			58·4	58·4	0·0					

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TABLE V. (*continued.*)

Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
August 21.			°	°	°			°	°	°
5000	From 4^h 30^m a.m. to 4^h 55^m a.m.	Below cloud.	43·5	43·5	0·0	From 6^h 36^m a.m. to 7^h 10^m a.m.	Below cloud.	43·5	43·5	0·0
4800			44·2	44·2	0·0			44·3	44·3	0·0
4600			45·0	45·0	0·0			45·0	45·0	0·0
4400			45·8	45·8	0·0			45·7	45·7	0·0
4200			46·5	46·5	0·0			46·4	46·4	0·0
4000			47·2	47·2	0·0			47·0	47·0	0·0
3800			47·9	47·9	0·0			47·7	47·7	0·0
3600			48·6	48·6	0·0			48·2	48·2	0·0
3400			49·4	49·4	0·0			48·8	48·8	0·0
3200			50·2	50·2	0·0			49·4	49·4	0·0
3000			51·0	51·0	0·0			50·1	50·1	0·0
2800			51·7	51·7	0·0			50·7	50·7	0·0
2600			52·4	52·4	0·0			51·4	51·4	0·0
2400			53·1	53·1	0·0			52·3	52·3	0·0
2200			53·8	53·8	0·0			53·2	53·2	0·0
2000			54·5	54·5	0·0			54·0	54·0	0·0
1800			55·2	55·2	0·0			54·9	54·9	0·0
1600			55·9	55·9	0·0			55·8	55·8	0·0
1400			56·6	56·6	0·0			56·7	56·7	0·0
1200			57·3	57·3	0·0			57·4	57·4	0·0
1000			58·0	58·0	0·0			58·0	58·0	0·0
800			58·7	58·7	0·0			58·7	58·7	0·0
600			59·4	59·4	0·0			59·4	59·4	0·0
400			60·2	60·2	0·0			60·2	60·2	0·0
200			61·1	61·1	0·0			61·0	61·0	0·0
0			61·8	61·8	0·0			62·0	62·0	0·0
September 1.										
4200	From 4^h 40^m p.m. to 5^h 32^m p.m.	. .	46·9	46·9	0·0	From 5^h 32^m to 6^h 1^m p.m.	. .	46·2	46·2	0·0
4000		. .	47·5	47·5	0·0		. .	46·5	46·5	0·0
3800		. .	48·0	48·0	0·0		. .	46·9	46·9	0·0
3600		. .	48·6	48·6	0·0		. .	47·4	47·4	0·0
3400		. .	49·3	49·3	0·0		. .	47·7	47·7	0·0
3200		. .	49·9	49·9	0·0		. .	48·1	48·1	0·0
3000		. .	50·5	50·5	0·0		. .	48·5	48·5	0·0
2800		. .	51·2	51·2	0·0		. .	49·1	49·1	0·0
2600		. .	52·0	52·0	0·0		. .	49·7	49·7	0·0
2400		. .	52·9	52·9	0·0		. .	50·2	50·2	0·0
2200		. .	53·9	53·9	0·0		. .	50·8	50·8	0·0
2000		. .	54·7	54·7	0·0		. .	51·5	51·5	0·0
1800		. .	55·5	55·5	0·0		. .	52·2	52·2	0·0
1600		. .	56·4	56·4	0·0		. .	53·0	53·0	0·0
1400		. .	57·3	57·3	0·0		. .	53·7	53·7	0·0
1200		. .	58·3	58·3	0·0					
1000		. .	59·2	59·2	0·0					
800		. .	60·5	60·5	0·0					
600		. .	61·7	61·7	0·0					
400		. .	63·0	63·0	0·0					
200		. .	64·2	64·2	0·0					
0		. .	65·7	65·7	0·0					
3000	From 6^h 1^m p.m. to 6^h 6^m p.m.	ouds above and below. ain falling from the lat- r on the earth all day.	53·5	53·5	0·0	From 6^h 6^m p.m. to 6^h 15 p.m.	Clouds above and below. Rain falling on the balloon.			
2800			53·6	53·6	0·0			53·5	53·5	0·0
2600			53·8	53·8	0·0			54·0	54·0	0·0
2400			53·9	53·9	0·0			54·5	54·5	0·0
2200			54·0	54·0	0·0			55·0	55·0	0·0
2000			54·0	54·0	0·0					
1800			54·0	54·0	0·0					
1600			54·2	54·2	0·0					

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TABLE V. (*continued.*)

Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
September 5.			°	°	°			°	°	°
5000	From $1^h\,3^m$ p.m. to $1^h\,12^m$ p.m.	Below cloud.	40·7	40·7	0·0	From $2^h\,31^m$ p.m. to $3^h\,6^m$ p.m.	..	47·2	47·2	0·0
4800			41·4	41·4	0·0		..	47·7	47·7	0·0
4600			42·2	42·2	0·0		..	48·1	48·1	0·0
4400			43·1	43·1	0·0		..	48·7	48·7	0·0
4200			44·0	44·0	0·0		..	49·3	49·3	0·0
4000			44·8	44·8	0·0		..	50·0	50·0	0·0
3800			45·6	45·6	0·0		..	50·6	50·6	0·0
3600			46·4	46·4	0·0		..	51·2	51·2	0·0
3400			47·2	47·2	0·0		..	51·8	51·8	0·0
3200			48·0	48·0	0·0		..	52·4	52·4	0·0
3000			48·8	48·8	0·0		..	53·0	53·0	0·0
2800			49·5	49·5	0·0		..	53·6	53·6	0·0
2600			50·2	50·2	0·0		..	54·2	54·2	0·0
2400			51·0	51·0	0·0		..	54·8	54·8	0·0
2200			51·9	51·9	0·0		..	55·4	55·4	0·0
2000			52·9	52·9	0·0		..	56·0	56·0	0·0
1800			53·8	53·8	0·0		..	56·6	56·6	0·0
1600			54·8	54·8	0·0		..	57·2	57·2	0·0
1400			55·8	55·8	0·0		..	57·8	57·8	0·0
1200			56·7	56·7	0·0		..	58·4	58·4	0·0
1000			57·5	57·5	0·0		..	59·2	59·2	0·0
800			58·4	58·4	0·0		..	59·7	59·7	0·0
600			59·3	59·3	0·0		..	60·2	60·2	0·0
400			60·2	60·2	0·0		..	61·2	61·2	0·0
200			61·1	61·1	0·0		..	62·0	62·0	0·0
0			62·0	62·0	0·0		..	62·8	62·8	0·0

On August 18, 20, 21, September 1, 5, and 8, there were no disturbing causes to any amount in operation within 5000 feet of the earth, and therefore the projected and adopted curves are identical.

TABLE V. (*continued.*)

Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
September 8.			°	°	°			°	°	°
5000	From 4h 47m p.m. to 4h 58m p.m.	..	..	50·0	..	From 4h 58m p.m. to 5h 6m p.m.	..	..	51·1	
4800		..	..	50·4	..		..	..	50·3	
4600		..	..	50·9	..		..	..	49·9	
4400		..	..	51·3	..		..	..	49·8	
4200		..	..	51·9	..		..	..	50·0	
4000		..	..	52·7	..		..	..	50·3	
3800		..	..	53·6	..		..	..	51·0	
3600		..	..	54·4	..		..	..	51·8	
3400		..	..	55·0	..		..	..	52·3	
3200		..	..	55·7	..		..	..	53·1	
3000		..	..	56·4						
2800		..	..	57·4						
2600		..	..	58·7						
2400		..	..	59·7						
2200		..	..	60·4						
2000		..	..	61·0						
1800		..	..	61·8						
1600		..	..	62·5						
1400		..	..	63·6						
1200		..	..	64·4						
1000		..	..	65·1						
800		..	..	65·8						
600		..	..	66·5						
400		..	..	67·3						
200		..	..	68·2						
0		..	..	69·0						
5000	..	..	..	..	..	From 5h 24m p.m. to 6h 10m p.m.	..	..	51·4	
4800	..	..	..	..	..		..	..	51·2	
4600	..	..	..	..	..		..	..	51·2	
4400	..	..	..	..	..		..	..	51·2	
4200	..	..	..	..	..		..	..	51·2	
4000	..	..	..	..	..		..	..	51·2	
3800	..	..	..	..	..		..	..	51·3	
3600	..	..	..	..	..		..	..	51·4	
3400	..	..	..	..	..		..	..	51·7	
3200	..	..	..	..	..		..	..	52·3	
3000	..	..	..	..	..		..	..	53·9	
2800	..	..	..	..	..		..	..	54·4	
2600	..	..	..	..	..		..	..	55·0	
2400	..	..	..	..	..		..	..	55·7	
2200	..	..	..	..	..		..	..	56·2	
2000	..	..	..	..	..		..	..	56·5	
1800	..	..	..	..	..		..	..	57·0	
1600	..	..	..	..	..		..	..	57·5	
1400	..	..	..	..	..		..	..	58·2	
1200	..	..	..	..	..		..	..	59·0	
1000	..	..	..	..	..		..	..	60·2	
800	..	..	..	..	..		..	..	61·0	
600	..	..	..	..	..		..	..	61·6	
400	..	..	..	..	..		..	..	62·5	
200	..	..	..	..	..		..	..	63·2	
0	..	..	..	..	..		..	..	64·8	

The next Table has been formed by taking the difference between the temperatures at every consecutive 100 feet, in every ascent and descent, up to 5000 feet.

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Table VI.—Showing the Decrease of Temperature with every

Height above the level of the sea.		July 17.	July 30.		August 18.		August 20.			August 21.	
		State of the Sky.									
		Cloudy.	Clear.	Cloudy.	Clear.	Cloudy.	Cloudy.			Cloudy.	
From	To	Ascending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Ascending.	Descending.
feet.	feet.	°	°	°	°	°	°	°	°	°	°
4900	5000	0·6	0·3	0·1	0·2	0·3	..	..	0·3	0·3	0·4
4800	4900	0·5	0·3	0·2	0·1	0·4	..	..	0·4	0·4	0·3
4700	4800	0·5	0·2	0·1	0·1	0·4	..	..	0·3	0·4	0·4
4600	4700	0·5	0·3	0·2	0·1	0·4	..	..	0·4	0·4	0·3
4500	4600	0·5	0·2	0·1	0·1	0·4	..	..	0·3	0·4	0·4
4400	4500	0·5	0·3	0·2	0·1	0·4	..	..	0·4	0·4	0·3
4300	4400	0·5	0·2	0·2	0·1	0·3	..	..	0·3	0·4	0·4
4200	4300	0·5	0·3	0·2	0·1	0·4	0·3	0·2	0·4	0·3	0·3
4100	4200	0·5	0·3	0·3	0·2	0·3	0·4	0·2	0·3	0·4	0·3
4000	4100	0·5	0·2	0·3	0·2	0·4	0·3	0·2	0·4	0·3	0·3
3900	4000	0·4	0·2	0·3	0·2	0·4	0·4	0·2	0·4	0·4	0·3
3800	3900	0·3	0·2	0·4	0·2	0·4	0·3	0·2	0·4	0·3	0·3
3700	3800	0·4	0·2	0·5	0·3	0·4	0·4	0·3	0·4	0·4	0·2
3600	3700	0·4	0·3	0·5	0·2	0·5	0·3	0·3	0·4	0·3	0·3
3500	3600	0·5	0·2	0·5	0·3	0·4	0·4	0·3	0·4	0·4	0·3
3400	3500	0·4	0·3	0·6	0·3	0·4	0·3	0·3	0·3	0·4	0·3
3300	3400	0·5	0·3	0·5	0·3	0·4	0·4	0·3	0·4	0·4	0·3
3200	3300	0·4	0·3	0·5	0·3	0·4	0·4	0·4	0·3	0·4	0·4
3100	3200	0·4	0·2	0·5	0·4	0·4	0·4	0·3	0·4	0·4	0·3
3000	3100	0·4	0·2	0·6	0·4	0·3	0·4	0·4	0·3	0·4	0·3
2900	3000	0·4	0·3	0·6	0·4	0·4	0·4	0·3	0·4	0·4	0·3
2800	2900	0·4	0·3	0·5	0·4	0·3	0·4	0·4	0·5	0·3	0·3
2700	2800	0·5	0·4	0·6	0·4	0·4	0·4	0·3	0·4	0·4	0·3
2600	2700	0·4	0·4	0·5	0·4	0·4	0·4	0·4	0·3	0·3	0·4
2500	2600	0·3	0·4	0·5	0·5	0·4	0·4	0·3	0·4	0·4	0·4
2400	2500	0·4	0·3	0·5	0·5	0·3	0·5	0·4	0·3	0·3	0·5
2300	2400	0·4	0·3	0·4	0·5	0·4	0·4	0·3	0·4	0·4	0·4
2200	2300	0·4	0·4	0·5	0·5	0·4	0·5	0·4	0·3	0·3	0·5
2100	2200	0·4	0·5	0·5	0·5	0·4	0·4	0·3	0·4	0·4	0·4
2000	2100	0·4	0·5	0·5	0·4	0·4	0·5	0·4	0·3	0·3	0·4
1900	2000	0·4	0·5	0·4	0·5	0·3	0·4	0·3	0·3	0·4	0·5
1800	1900	0·5	0·6	0·4	0·4	0·4	0·5	0·4	0·3	0·3	0·4
1700	1800	0·4	0·6	0·5	0·5	0·3	0·4	0·3	0·2	0·3	0·5
1600	1700	0·5	0·5	0·4	0·5	0·4	0·5	0·4	0·2	0·4	0·4
1500	1600	0·4	0·5	0·3	0·4	0·3	0·4	0·3	0·2	0·3	0·5
1400	1500	0·5	0·5	0·3	0·5	0·4	0·5	0·4	0·2	0·4	0·4
1300	1400	0·4	0·7	0·3	0·6	0·5	0·4	..	..	0·3	0·4
1200	1300	0·5	0·7	0·4	0·6	0·4	0·5	..	..	0·4	0·3
1100	1200	0·4	0·7	0·5	0·6	0·5	0·4	..	..	0·3	0·3
1000	1100	0·4	0·6	0·5	0·7	0·4	0·5	..	..	0·4	0·3
900	1000	0·4	0·5	0·5	0·7	0·4	0·4	..	..	0·3	0·3
800	900	0·4	0·6	0·5	0·8	0·4	0·5	..	..	0·4	0·4
700	800	0·4	0·6	0·4	0·8	0·4	0·5	..	..	0·3	0·3
600	700	0·5	0·6	0·5	0·8	0·4	0·5	..	..	0·4	0·4
500	600	0·5	0·8	0·4	0·8	0·4	0·5	..	..	0·4	0·4
400	500	0·5	0·8	0·5	0·8	0·4	0·5	..	..	0·4	0·4
300	400	0·5	0·9	0·5	0·8	0·4	0·5	..	..	0·4	0·4
200	300	0·5	0·9	0·5	0·8	0·4	0·5	..	..	0·5	0·4
100	200	0·5	1·0	0·5	0·8	0·4	0·6	..	..	0·4	0·5
0	100	0·5	1·1	0·5	0·9	0·5	0·6	..	..	0·3	0·5

Increase of Height of 100 feet up to 5000 feet.

September 1.			September 5.		September 8.			Mean.			
State of the Sky.											
Partially clear.			Partially clear.	Cloudy.	Cloudy.						
Ascending.	Descending.	Ascending.	Ascending.	Descending.	Ascending.	Descending.	Descending.	Cloudy.	Number of observations.	Clear.	Number of observations.
0	0	0	0	0	0	0	0	0		0	
..	..	..	0·3	0·1	0·2	0·4	0·1	0·3	10	0·3	3
..	..	..	0·3	0·1	0·2	0·4	0·1	0·3	10	0·3	3
..	..	..	0·4	0·2	0·2	0·2	..	0·3	9	0·3	3
..	..	..	0·4	0·2	0·3	0·2	..	0·3	9	0·3	3
..	..	..	0·5	0·3	0·2	0·1	0·1	0·3	10	0·3	3
..	..	..	0·4	0·3	0·2	0·1	0·1	0·3	10	0·3	3
..	..	..	0·5	0·3	0·3	0·1	0·0	0·3	10	0·3	3
..	..	..	0·4	0·4	0·3	0·1	0·0	0·3	12	0·3	3
0·3	0·2	..	0·4	0·3	0·4	0·3	0·0	0·3	12	0·3	5
0·3	0·2	..	0·4	0·3	0·4	0·4	0·0	0·3	12	0·3	5
0·3	0·2	..	0·4	0·3	0·5	0·4	0·1	0·3	12	0·3	5
0·3	0·2	..	0·4	0·3	0·4	0·4	0·1	0·3	12	0·3	5
0·3	0·3	..	0·4	0·3	0·4	0·4	0·1	0·3	12	0·3	5
0·3	0·2	..	0·4	0·3	0·4	0·4	0·1	0·3	12	0·3	5
0·3	0·2	..	0·4	0·3	0·3	0·4	0·1	0·3	12	0·3	5
0·3	0·2	..	0·4	0·3	0·3	0·4	0·2	0·3	12	0·3	5
0·3	0·2	..	0·4	0·3	0·3	0·4	0·3	0·4	12	0·3	5
0·3	0·2	..	0·4	0·3	0·4	0·4	0·3	0·4	12	0·3	5
0·3	0·2	..	0·4	0·3	0·3	..	0·3	0·4	11	0·3	5
0·3	0·2	..	0·4	0·3	0·4	..	0·3	0·4	11	0·3	5
0·4	0·3	..	0·3	0·3	0·5	..	0·1	0·4	11	0·3	5
0·4	0·3	..	0·4	0·3	0·5	..	0·2	0·4	11	0·4	5
0·4	0·3	..	0·3	0·3	0·5	..	0·4	0·4	11	0·4	5
0·4	0·3	..	0·4	0·3	0·5	..	0·4	0·4	11	0·4	5
0·4	0·3	..	0·4	0·3	0·5	..	0·4	0·4	11	0·4	5
0·4	0·3	..	0·4	0·3	0·5	..	0·3	0·4	11	0·4	5
0·4	0·3	..	0·4	0·3	0·4	..	0·3	0·4	11	0·4	5
0·4	0·3	..	0·5	0·3	0·3	..	0·2	0·4	11	0·4	5
0·4	0·3	..	0·5	0·3	0·3	..	0·2	0·4	11	0·4	5
0·4	0·4	..	0·5	0·3	0·3	..	0·1	0·4	11	0·4	5
0·4	0·4	..	0·4	0·3	0·4	..	0·2	0·4	11	0·4	5
0·4	0·4	..	0·5	0·3	0·4	..	0·3	0·4	11	0·4	5
0·4	0·4	..	0·5	0·3	0·3	..	0·2	0·3	11	0·5	5
0·4	0·4	..	0·5	0·3	0·4	..	0·3	0·4	11	0·5	5
0·4	0·4	0·4	0·5	0·3	0·5	..	0·3	0·4	11	0·5	6
0·5	0·3	0·4	0·5	0·3	0·5	..	0·4	0·4	11	0·5	6
0·5	..	..	0·4	0·3	0·4	..	0·4	0·4	9	0·5	4
0·5	..	..	0·5	0·3	0·4	..	0·4	0·4	9	0·5	4
0·4	..	..	0·4	0·3	0·3	..	0·6	0·4	9	0·5	4
0·5	..	..	0·4	0·3	0·4	..	0·6	0·4	9	0·5	4
0·5	..	..	0·4	0·3	0·3	..	0·4	0·4	9	0·5	4
0·6	..	..	0·5	0·4	0·4	..	0·4	0·4	9	0·6	4
0·6	..	..	0·4	0·3	0·3	..	0·3	0·4	9	0·6	4
0·5	..	..	0·5	0·4	0·4	..	0·3	0·4	9	0·6	4
0·6	..	..	0·4	0·4	0·4	..	0·4	0·4	9	0·6	4
0·6	..	..	0·5	0·4	0·4	..	0·5	0·4	9	0·7	4
0·7	..	..	0·4	0·4	0·4	..	0·3	0·4	9	0·7	4
0·7	..	..	0·5	0·4	0·5	..	0·4	0·5	9	0·8	4
0·7	..	..	0·4	0·4	0·4	..	..	0·5	9	0·8	4
0·8	..	..	0·5	0·4	0·4	..	..	0·5	9	0·9	4

An inspection of this Table shows that the largest numbers are those situated at the bottom, and the smallest at the top of each column in all states of the sky, and therefore that the decline of temperature in equal spaces was largest in that space next the earth, and gradually less with increase of elevation.

The numbers in the last column of the Table show the average value at each 100 feet, the one in cloudy states of the sky, and the other in partially clear states, with the number of experiments upon which each result is based.

FROM THESE RESULTS THE DECLINE OF TEMPERATURE

When the Sky was Cloudy

For the first 300 feet was ......0°·5 for every 100 feet.
From 300 feet to 3400 feet was 0°·4 ,, ,,
,, 3400 ,, 5000 ,, 0°·3 ,, ,,

Therefore in cloudy states of the sky the temperature of the air decreases nearly uniformly with the height above the surface of the earth nearly up to the cloud.

When the Sky was partially Cloudy.

In the first ......100 feet there was a decline of 0°·9
From 100 feet to 300 ,, ,, ,, 0°·8 for each 100 feet.
,, 300 ,, 500 ,, ,, ,, 0°·7 ,, ,,
,, 500 ,, 900 ,, ,, ,, 0°·6 ,, ,,
,, 900 ,, 1800 ,, ,, ,, 0°·5 ,, ,,
,, 1800 ,, 2900 ,, ,, ,, 0°·4 ,, ,,
,, 2900 ,, 5000 ,, ,, ,, 0°·3 ,, ,,

The decline of temperature near the earth with a partially clear sky is nearly double of that with a cloudy sky; at elevations above 4000 feet, the changes for 100 feet seem to be the same in both states of the sky.

In some cases, as on July 30, the decline of temperature in the first 100 feet was as large as 1°·1.

From these results we may conclude that in a cloudy state of the sky the decline of temperature is nearly uniform up to the clouds; that with a clear sky the greatest change is near the earth, being a decline of 1° in less than 100 feet, gradually decreasing, as in the general law indicated in the preceding Section, till it requires a space of 300 feet at the height of 5000 feet for a change of 1° of temperature. These results lead to the same conclusion as before, viz. that the theory of gradation of 1° of temperature for every 300 feet of elevation must be abandoned. As regards the law indicated by all these experiments, it is far more natural and consistent, than that a uniform rate of decrease could be received as a physical law up even to moderate elevations.

§ 6. VARIATION OF THE HYGROMETRIC CONDITION OF THE AIR WITH ELEVATION.

All the adopted readings of the temperature of the dew-point in Section 4 were laid down on diagrams of a large scale, and their points were joined; and as it was evident that there were strata of moist air, and that the changes do not follow any regular decrease as in the case of the temperature of the air, it was therefore not considered prudent to adopt any curve with the view of obtaining normal results, but to use the projected curve as simply found by joining the points as stated above. From the readings at every 1000 feet of elevation the next Table was formed; other readings were taken at angular intermediate points, and these are included in the remarks following the Table. The numbers under the heading of "Tension of Vapour" are formed by using "Regnault's Tables," and the degree of humidity in the next column has been calculated by using the observed temperature of the air corresponding to the observed temperature of the dew-point.

TABLE VII.—Showing the Variation of the Hygrometric condition of the Air at every 1000 feet of Height.

Height, in feet, above the mean level of the sea.	Humidity of the Air.				
	Ascending.				
	Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.
July 17.					
26000	From $9^h 43^m$ a.m. to $11^h 1^m$ a.m.	Above cloud.	Unknown, but certainly less than −20°.	Unknown, but certainly less than ·017.	Unknown, but certainly less than
25000					
24000					
23000					
22000					
21000			°	in.	
20000			16·0	·089	48
19000			24·1	·130	54
18000			23·8	·128	62
17000			23·0	·123	66
16000			22·8	·122	68
15000			23·5	·126	72
14000			23·9	·128	78
13000			22·0	·118	82
12000			23·8	·128	92
11000			23·3	·125	89
10000			19·0	·103	73
9000			21·0	·113	70
8000		In cloud.	27·9	·152	84
7000			30·0	·167	78
6000			32·0	·181	90
5000			32·0	·181	76
4000		Below cloud.	34·0	·196	65
3000			39·6	·243	73
2000			44·7	·296	75
1000			49·7	·357	77
0			55·0	·433	79

July 17.—At the earth's surface the dew-point was 55°, which seemed to decrease gradually to the height of about 4000 feet, the relative humidity decreasing from 79 to 65 within the same space; on entering a cloud the rate of the decrease of the dew-point was checked, and for a space of 3000 feet was almost constant, differing but little from 32°, whilst the relative humidity increased to 91 at 5800 feet. On leaving the cloud at 8000 feet high, and between that and 9600 feet, both the dew-point and the relative humidity decreased quickly, the former to 17°·9 and the latter to 65. From 9600 feet to 11,500 feet, whilst the temperature of the air remained at 26°, the dew-point increased to 24°·8, and the relative humidity to 95, closely approaching to saturation. From the height of 12,000 feet to 19,000 feet, the amount of water in the air was almost constant, the dew-point undergoing scarcely any

variation, but during which time there was a great increase of temperature, and consequently the relative humidity decreased with rapidity from 95 to 39. The balloon then fell from 19,500 feet to 19,200 feet, the temperature of the air decreased to 38°, and the dew-point increased from 19½° to 21°, and the humidity increased to 49. After 19,200 feet the dew-point decreased with rapidity to 16° at 20,000 feet, with a humidity of 48; and afterwards with great rapidity to a dew-point of less than −12° at 21,000 feet; and at heights exceeding this the dew-point is unknown, but was certainly lower than −20°, and probably as low as −30° up to 24,000 feet; from the observations of the dry- and wet-bulb thermometers it seems to have been as low as −50° at 25,000 feet; therefore the tension of vapour above 20,000 feet must have varied from about 0·015 in. to less than 0·01 in., and the degree of humidity to have decreased to 2, or even less. In this series we can distinctly trace a stratum of moist air in the cloud above 4000 feet, and again between the heights of 9500 feet and 11,500 feet. From 11,500 feet to 19,000 feet the tension of vapour differed but very little from 0·13 inch; then the amount of water present in the same mass of air was nearly constant for 8000 feet in vertical height; immediately after this there were some irregularities, and above 20,000 feet the air was dry, being almost free from vapour.

TABLE VII. (*continued.*)

Height, in feet, above the mean level of the sea.	Humidity of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.	Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.
July 30.	From 4h 36m p.m. to 5h 43m p.m.	Misty.	°	in.		From 5h 44m p.m. to 6h 30m p.m.		°	in.	
6000			33·8	·194	68		...	33·0	·188	61
5000			37·2	·222	66		...	36·7	·218	67
4000			39·5	·242	63		...	38·5	·233	66
3000			41·4	·261	65		...	42·3	·270	65
2000			43·2	·279	54		...	41·8	·265	53
1000			44·2	·290	51		...	45·8	·308	52
0			53·0	·403	54		...	47·4	·328	48

July 30.—The temperature of the dew-point in this ascent was constantly varying: on the ground it was 53°, at 1000 feet it was 44¼°, but at intermediate points it was sometimes on one side and sometimes on the other, to the amount of 1° or 2° from the curve-line joining these points; then up to 2400 feet there was a stratum of moist air, and above 3600 feet there were strata of moist and dry air alternately for 2000 feet; higher than this there was a stratum of dry air from 5600 to 6400 feet, and higher still one of moist from 6500 feet to the highest point reached: these terms, moist and dry, have reference to a curve-line, which was made to pass near every point as laid down from observation; and the same phenomena generally prevailed during the descent. The relative humidity generally increased to the highest point reached.

TABLE VII. (*continued.*)

Height, in feet, above the mean level of the sea.	Hygrometrical results. Ascending. Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.	Descending. Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.
August 18.			°	in.				°	in.	
11000	From 1h 2m p.m. to 1h 21m p.m.	...	26·0	·141	59	From 1h 22m p.m. to 1h 48m p.m.	...	24·5	·132	51
10000		...	28·0	·153	58		...	27·0	·147	51
9000		...	31·8	·179	63		...	28·8	·158	49
8000		...	33·9	·195	65		...	37·0	·220	61
7000		...	35·9	·211	68		...	37·0	·220	53
6000		...	38·0	·229	71		...	37·5	·225	54
5000		...	41·0	·257	75		...	41·5	·265	66
4000		In a cumulus cloud.	47·6	·329	91		...	46·6	·318	76
3000			50·0	·361	90					
2000		...	51·0	·374	79					
1000		...	52·5	·396	72					
0		...	57·0	·465	62					
23000	From 1h 49m p.m. to 2h 59m p.m.	...	− 8·0	·029						
22000		...	−10·0	·026						
21000		...	−11·0	·025						
20000		...	− 8·0	·029	22					
19000		...	− 2·0	·040	22					
18000		...	1·8	·047	30	... From 3h 0m p.m. to 4h 6m p.m.	...	1·0	·046	31
17000		...	8·0	·062	27		Above cloud.	3·0	·050	32
16000		...	14·0	·082	42			5·0	·054	33
15000		...	19·2	·104	52			7·0	·060	34
14000		...	23·8	·128	61			9·2	·065	36
13000		...	24·7	·133	67			11·5	·072	36
12000		...	24·0	·129	59			14·0	·082	36
11000		...	28·0	·153	52			14·0	·082	34
10000		...	33·0	·188	52		...	15·2	·086	28
9000		...	36·1	·213	53		...	22·0	·118	35
8000		...	39·0	·238	57		...	34·5	·199	55
7000		...	39·2	·239	64		...	37·2	·222	61
6000		...	40·8	·255	59		In cloud.	40·0	·247	61
5000		...	42·2	·269	59			43·2	·279	62
4000		...	45·8	·308	70		... Below cloud.	46·2	·313	77
3000		...	...	...	...	...		49·0	·348	74
2000		...	...	...	...	...		51·5	·385	71
1000		...	...	...	...	...		54·0	·418	69
0		...	...	...	...	...		57·0	·465	66

August 18.—The temperature of the dew-point decreased from 57° on the ground to 52½° at 1000 feet, increased from 52½° at 1000 feet to 53¼° at 1700 feet whilst passing through mist, decreased to 50° at 2000 feet, and varied but little till 3800 feet was passed; the degree of humidity varying from 62 on the ground to 96 at 3800 feet when in a cumulus cloud. The dew-point decreased rather quickly to 41° at 5000 feet, and with less rapidity to 26° at 11,000 feet, the humidity varying from 96 at 3800 feet to 59 at 11,000 feet. Whilst almost stationary in elevation for some time, at the highest point the temperature of the air increased, whilst that of the dew-point decreased, so that the degree of humidity changed from 59 to 51. The balloon then descended: the temperature of the dew-point increased gradually to 31° at 8200 feet, and to 38° at 7800 feet: the humidity was 61 at the lower elevation: the dew-point remained nearly at the temperature of 37° from 7800 feet to 6000 feet, and rose to 48° at 3500 feet—its lowest

TABLE VII. (*continued.*)

Height, in feet, above the mean level of the sea.	Hygrometrical results.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.	Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.
August 20.										
5000	From $6^h\,22^m$ p.m. to $6^h\,47^m$ p.m.		°	in.		From $6^h\,49^m$ p.m. to $7^h\,20^m$ p.m.		°	in.	
4000		...	46·2	·313	88		...	44·2	·290	84
3000		...	48·9	·346	84		...	46·6	·318	83
2000		...	50·0	·361	75		...	49·0	·349	82
1000		...	52·3	·393	69		...	51·7	·384	81
0		...	62·0	·556	83					
5000	From $7^h\,1^m$ p.m. to $8^h\,5^m$ p.m.	In cloud.	42·3	·270	88					
4000		...	44·2	·290	83					
3000		...	46·0	·311	77					
2000		...	50·5	·367	80					
1000		...	51·7	·384	81					
0										

point: the humidity increased from 53 at 7000 feet to 77 at 3500 feet. The balloon then ascended, and the dew-point fell to 37° at 8000 feet, and the humidity from 76 to 61.

The dew-point then increased somewhat to 39½° at 8500 feet, with a humidity of 65: from this elevation the dew-point decreased to 21° at 11,600 feet, with a degree of humidity of 51. The dew-point then turned to increase, and was 25½° at 12,400 feet, giving a humidity of 57 at this elevation; it then decreased gradually to 23° at 14,500 feet, and then rapidly to −8½° at 20,100 feet: the relative humidity was 59 at 12,400 feet, and 22 at 20,100 feet. Above 20,000 feet a dry stratum of air was entered and no dew was deposited on either of the hygrometers, their bulbs being reduced to a temperature of −10°.

In descending, the dew-point increased steadily to 14° at 12,000 feet, remained at this reading till nearly 10,000 feet, then increased rapidly to 34½° at 8000 feet, and then gradually and almost uniformly to 57° on the ground: the degree of humidity increased from 31 at 18,000 feet to 36 at 14,000 feet, remained at this value to 12,000 feet, decreased to 28 at 10,000 feet and then increased to 77 at 4000 feet, and was 66 on reaching the ground. In this series a narrow stratum of moist air was passed through between 1000 and 2000 feet from the earth, and then another on passing through a cumulus cloud at the height of 3800 feet; above this to 11,000 feet there was a constant decrease in the amount of water; the balloon then descended and the vapour increased steadily to 8000 feet, then a stratum of moist air was met with from 1000 to 2000 feet in thickness; from 6000 feet to 3500 feet on descending, and again from 3500 to 7000 feet on ascending, there was an increase and decrease respectively; between 8000 and 9000 feet and between 11,000 and 12,000 feet dry strata were passed; then for 2000 feet there was but little variation in the humidity of the air, above 15,000 feet there was a rapid decrease in the amount of vapour, till the air became very dry above 20,000 feet. In the descent one stratum only of moist air was passed through, viz. between 13,000 feet and 9000 feet from the earth.

August 20.—Between 400 and 600 feet a dry stratum of air was passed, then there was but little variation in the temperature of the dew-point, and the air was for the most part humid during the ascent.

TABLE VII. (*continued.*)

Height, in feet, above the mean level of the sea.	Hygrometrical results.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.	Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.
August 21.			°	in.				°	in.	
14000	From 4^h 30^m a.m. to 5^h 51^m a.m.	Above cloud.	$-14{\cdot}0$	·022	18	From 5^h 52^m a.m. to 7^h 10^m a.m.	Above cloud.	$-22{\cdot}0$	·015	12
13000			$-\ 3{\cdot}7$	·036	28			$-13{\cdot}0$	·023	17
12000			$+\ 3{\cdot}0$	·050	36			0·0	·044	28
11000			10·0	·068	43			$+13{\cdot}1$	·078	43
10000			14·1	·082	46			19·0	·103	51
9000			20·8	·112	56			18·0	·098	42
8000			25·2	·136	61			19·0	·103	38
7000			32·0	·181	71		In cloud.	32·0	·181	58
6000		In cloud.	39·0	·238	97			37·5	·225	89
5000			41·6	·263	93		Below cloud.	38·0	·229	81
4000		Below cloud.	40·8	·255	78			40·5	·252	78
3000			46·8	·321	86			45·7	·307	85
2000			50·9	·373	88			47·0	·323	77
1000			56·8	·462	96			49·7	·357	74
0			60·0	·518	94	...	...	56·0	·449	81

August 21.—The temperature of the dew-point decreased from 60° on the ground to 57° at 400 feet, then increased to 59° from 500 to 700 feet whilst passing through a thick mist, and to 60° at 1000 feet; a decline then took place to 50°·8 at 1300 feet, and 50°·9 at 2000 feet; from 2000 feet to 3200 feet there was at first a gradual, then more rapid decline to 40°·8 at 4000 feet; on entering cloud the dew-point increased to 41°·6, and on leaving it at about 6000 feet there was a sudden fall of 2°. The relative humidity was 94 on the ground: the air was saturated for 200 feet from 500 to 700 feet; the humidity was 74 at 1000 feet, 79 at 1300 feet, and 97 in the cloud. Above the cloud the dew-point decreased quickly and with but slight irregularities till the height of 10,400 feet, where it was 14½°, with a humidity of 48; at 14,000 feet the dew-point was −14°, and the air was dry, the relative humidity being 18. Above 14,000 feet the temperature of the dew-point declined to −20°, with a humidity of 12 only. During the half-hour this height was maintained the temperature of the air increased, whilst that of the dew-point diminished, so that the air became drier. On descending the air continued dry, the dew-point increased from −22° at 14,000 feet to +19° at 10,000 feet, the humidity increasing to 51; there was but little variation in the dew-point in the next 2000 feet, but during this space the temperature of the air increased 7°, so that the relative humidity was irregular. At 7500 feet the dew-point was 20°, at 6900 feet it was 42°; on approaching the clouds at the former height the relative humidity was 38, and at the latter it was 88. Whilst passing through the cloud both the temperatures of the air and dew-point declined, the latter to 38½°, and the humidity was 89. On descending below the cloud the dew-point increased gradually from 38½° at 4000 feet high, then quickly to 45°·7 at 3000 feet, then fell to 44°·7 at 2500 feet, then increased to 56° on reaching the ground. At 5800 feet the relative humidity was 83, between 2500 feet and 1500 feet it was 76 or 77, and it was 71 on the earth.

In this series, till the clouds were passed, there were two or three layers of moist air; but from the time of passing above the clouds, the air was constantly increasing in dryness till the greatest height was attained, and

TABLE VII. (*continued.*)

Height, in feet, above the mean level of the sea.	Hygrometrical results.									
	Ascending.					Descending.				
	Between what times.	Circum-stances.	Tempe-rature of the dew-point.	Elastic force of vapour.	Degree of humi-dity.	Between what times.	Circum-stances.	Tempe-rature of the dew-point.	Elastic force of vapour.	Degree of humi-dity.
September 1.	From 4^{h} 52^{m} p.m. to 5^{h} 35^{m} p.m.		°	in.		From 5^{h} 36^{m} p.m. to 6^{h} 2^{m} p.m.		°	in.	
4000		...	37·6	·225	69		...	37·0	·220	70
3000		...	43·2	·279	76		...	38·7	·235	69
2000		...	47·9	·334	78		...	47·3	·327	86
1000		...	50·3	·365	72					
0										
4000	From 6^{h} 3^{m} p.m. to 6^{h} 6^{m} p.m.	Clouds above and below; rain falling on the earth.								
3000			45·8	·308	75					
2000			46·0	·311	74					
1000										
0										
September 5.	From 1^{h} 3^{m} to 1^{h} 53^{m} p.m.	Above cloud.								
24000			−36·0	...	16					
23000			−28·0	...	21					
22000			−20·5	...	32					
21000			−15·0	...	33					
20000			− 5·2	...	50	...	...	−37·0	...	8
19000			−20·0	...	20	...	...	−35·0	...	8
18000			− 4·0	...	41	...	...	−33·2	...	9
17000			+ 8·0	·062	76	...	...	−31·7	...	9
16000			13·2	·078	84	...	...	−30·0	...	9
15000			16·7	·093	89	...	From 2^{h} 7^{m} to 3^{h} 6^{m} p.m.	−28·5	...	10
14000			19·2	·104	88	...		−26·5	...	10
13000			22·5	·120	91	...		−24·5	...	10
12000			22·0	·118	81	...		−21·0	...	11
11000			26·0	·141	85	...		− 8·0	...	17
10000			26·5	·144	81	...		+ 3·0	·050	27
9000			27·5	·152	75	...		7·5	·061	29
8000			29·5	·163	71	...		12·7	·077	33
7000			35·0	·204	77	...		20·5	·110	43
6000		Below cloud.	36·2	·214	98	...		21·0	·113	39
5000			38·5	·233	91	...		21·5	·115	36
4000			40·8	·255	86	...	...	22·5	·120	33
3000			43·2	·279	81	...	...	38·7	·235	58
2000			45·5	·305	76	...	...	42·8	·275	62
1000			49·9	·360	76	...	...	46·2	·313	63
0			...	...	...	...	...	50·0	·361	64

increasing in dampness in the descent to 10,000 feet; then a dry stratum of air was met with, till on approaching the clouds and passing through them a moist stratum was passed; below the clouds there were but slight variations till the descent was completed.

September 1.—The changes of the dew-point in this ascent were more frequent and more abrupt than on August 20; there seemed to be different layers of moist air, varying in thickness from 200 to 300 and 400 feet up to 3000 feet, and above this the variations were smaller in amount and less in number. In the descent a moist stratum of air was met with between the heights of 2000 and 1300 feet.

September 5.—The temperature of the dew-point increased from 48½° on leaving the earth to 50½° at 700 feet; it then began to decrease, and was

TABLE VII. (*continued.*)

Height, in feet, above the mean level of the sea.	Hygrometrical results.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.	Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.
September 8.	From $4^h\ 47^m$ p.m. to $4^h\ 58^m$ p.m.		°	in.		From $5^h\ 0^m$ p.m. to $5^h\ 9^m$ p.m.		°	in.	
4000		In cloud.	48·6	·343	86		In cloud.	49·1	·349	96
3000		Below cloud.	51·8	·385	85					
2000			55·9	·447	83					
1000			59·5	·509	82					
0			61·5	·546	77					
5000	From $5^h\ 10^m$ p.m. to $5^h\ 18^m$ p.m.	...	33·5	·192	44	From $5^h\ 19^m$ p.m. to $6^h\ 10^m$ p.m.	...	45·0	·299	53
4000		...	50·8	·371	94		...	48·2	·338	89
3000		...	...	...	...		...	46·0	·311	75
2000		...	...	...	...		...	54·0	·418	
1000		...	...	...	...		...	58·0	·482	
0										

38°·9 between 4300 and 4700 feet, and declined to 36¼° from 5600 feet to 6800 feet. The relative humidity increased with slight variations from 67 on leaving the earth to 100 at 6800 feet in a cumulus cloud; on passing out of the cloud, the dew-point declined quickly to 30¼° at 7600 feet, then uniformly to 26½° at 9800 feet: the relative humidity decreased to 69 at 7600 feet, and increased to 81 at 10,000 feet; in the dew-point a slight increase then took place to 27° at 10,800 feet, and then a decrease to 19½° at 12,600 feet. The dew-point increased to 22½° at 13,000 feet, and the humidity to 91 at this elevation. The dew-point was 10½° at 16,800 feet, and the humidity was 77. A rapid decrease of the dew-point then took place to −21° at 19,200 feet, and then as rapid an increase to −7° at 19,500 feet and to −3° at 20,100 feet: the humidity declined to 18 at 19,200 feet, and increased to 36 at 19,500 feet, and to 50 at 20,100 feet.

Above this point the temperature of the dew-point rapidly declined: at 24,000 feet no dew was deposited on Regnault's Hygrometer, and at higher points still it must have been less than −50°.

In the descent there were no marked irregularities till the balloon was within 8000 feet of the earth, when the dew-point increased and decreased two or three times in the next 4000 feet, after which it declined gradually to the earth.

The variations in the amount of moisture in the air on this occasion were few and to small amounts after passing out of the cloud in which the air was saturated. About 1800 feet a dry stratum of air was passed, and after 2000 feet the amount of vapour became smaller, and was exceedingly small in amount at the higher elevations.

September 8.—The humidity in this ascent increased from the earth to the clouds with very little variation, but on passing above them the decrease was very great; the two latter results are not used in the formation of the next Table.

TABLE VIII.—Showing the Degree of Humidity

Height above the level of the sea.	July 17.		July 30.		August 18.				August 20.		
	State of the sky.										State of
	Cloudy.		Partially clear.	Cloudy.	Clear.		Clear.		Cloudy.		Cloud
	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.
feet.											
29000	Unknown.										
28000											
27000											
26000											
25000											
24000		..	..	..	..	..	..	..	..	..	..
23000	...	..	..	..	..	..	..	..	..	..	..
22000	...	..	..	..	..	..	..	..	..	..	..
21000	...	..	..	..	..	..	..	..	..	..	..
20000	48	..	..	..	..	..	22	..	..	..	..
19000	54	..	..	..	..	..	22	..	..	..	..
18000	62	..	..	..	..	..	30	31	..	..	..
17000	66	..	..	..	..	..	27	32	..	..	..
16000	68	..	..	..	..	..	42	33	..	..	..
15000	72	..	..	..	..	..	52	34	..	..	..
14000	78	..	..	..	..	..	61	36	..	..	..
13000	82	..	..	..	..	..	67	36	..	..	..
12000	92	..	..	..	..	..	59	36	..	..	..
11000	89	..	..	..	59	51	52	34	..	..	..
10000	73	..	..	..	58	51	52	28	..	..	..
9000	70	..	..	..	63	49	53	35	..	..	..
8000	84	..	..	..	65	61	57	55	..	..	..
7000	78	..	..	..	68	53	64	61	..	..	..
6000	90	..	68	61	71	54	59	61	..	..	..
5000	76	..	66	67	75	66	59	62	..	..	88
4000	65	..	63	66	91	76	70	77	88	84	83
3000	73	..	65	65	90	..	..	74	84	83	77
2000	75	..	54	53	79	..	..	71	75	82	80
1000	77	..	51	52	72	..	..	69	69	81	81
0	79	..	54	48	62	..	..	66	83	..	..

On August 21 the observations were taken very early in the morning, in fact directly after sunrise, and it will be seen that the degree of humidity at the elevations exceeding 10,000 feet are very much smaller than in any other ascent at the same elevations; from this it would seem that a diurnal range takes place in this element at this elevation, as in the temperature of the air; so that in comparing the laws of moisture indicated by one ascent with those of another, the times of the day at which the experiment was made must be taken into account. It is possible, indeed almost certain, that at the height of 14,000 feet and above, the air would become more humid as the day advanced, the vapour rising from the upper surface of the clouds and ascending into the higher regions by the action of the sun.

An inspection of the numbers in this Table shows that the moisture in the air is very different at different times, both in its amount and distribution.

The degree of humidity in cloudy states of the sky in the lower strata of at every 1000 feet up to 29,000 feet.

August 21.		September 1.			September 5.		September 8.				Mean.				Height above the level of sea.
the sky.		State of the sky.													
Cloudy.		Partially clear.	Cloudy.	Cloudy.	Partially clear.	Cloudy.	Cloudy.		Cloudy.						
Ascending.	Descending.	Ascending.	Descending.	Ascending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Cloudy.	No. of observations.	Clear.	No. of observations.	feet.
													Unknown.		29000
															28000
															27000
															26000
															25000
..	..	..	..	..	16	..	..	..	..	..	..	..	16	1	24000
..	..	..	..	..	21	..	..	..	..	..	..	..	21	1	23000
..	..	..	..	..	32	..	..	..	..	..	..	..	32	1	22000
..	..	..	..	..	33	..	..	..	..	..	..	..	33	1	21000
..	..	..	..	..	50	..	..	..	..	..	..	..	36	2	20000
..	..	..	..	..	20	..	..	..	..	..	..	..	21	2	19000
..	..	..	..	..	41	..	..	..	..	..	..	..	33	3	18000
..	..	..	..	..	76	..	..	..	..	..	..	..	45	3	17000
..	..	..	..	..	84	..	..	..	..	..	..	..	53	3	16000
..	..	..	..	..	89	..	..	..	..	..	..	..	58	3	15000
18	12	..	..	..	88	..	..	..	..	..	15	2	43	3	14000
28	17	..	..	..	91	..	..	..	..	..	23	2	48	3	13000
36	28	..	..	..	81	..	..	..	..	..	32	2	48	3	12000
43	43	..	..	..	85	..	..	..	..	..	43	2	52	5	11000
46	51	..	..	..	81	..	..	..	..	..	48	2	52	5	10000
56	42	..	..	..	75	..	..	..	..	..	49	2	54	5	9000
61	38	..	..	..	71	..	..	..	..	..	49	2	58	7	8000
71	58	..	..	..	77	..	..	..	..	..	63	2	64	7	7000
97	89	..	..	..	98	..	..	..	..	..	82	3	68	6	6000
93	81	..	..	..	91	..	..	..	..	..	83	5	69	6	5000
78	78	69	70	..	86	..	86	96	94	89	80	10	76	7	4000
86	85	76	69	75	81	..	85	..	..	75	80	12	76	5	3000
88	77	78	86	74	76	..	83	..	..	..	77	11	71	5	2000
96	74	72	..	..	76	..	82	..	..	..	77	8	68	5	1000
94	81	..	..	..	76	..	77	..	..	..	77	6	63	4	0

the air, as might be expected, is very much greater than in clear states; and above the clouds, at the same height, there are very different degrees in the different experiments.

The laws of moisture are indicated by these experiments, as found by taking the means of the numbers under the same state of the sky, and are as follows:—

With an overcast sky, the degree of humidity on the earth was	77	from	6	experiments.
At 1000 feet	77	,,	8	,,
2000 ,, ...	77	,,	11	,,
3000 ,, ...	80	,,	12	,,
4000 ,, ...	80	,,	10	,,
5000 ,, ...	83	,,	5	,,
6000 ,, ...	82	,,	3	,,

The laws of moisture here indicated are—an almost uniform state of humidity of the air to the height of 3000 feet, viz. 77; then a sudden increase to 80 in the next 1000 feet, and to 83 by 5000 feet, which slightly decreased to 82 by 6000 feet.

When the sky was partially clear, the degree of humidity

On the ground was	63	from	4	experiments.
At 1000 feet	68	,,	5	,,
2000 ,,	77	,,	5	,,
3000 ,,	76	,,	5	,,
4000 ,,	76	,,	7	,,
5000 ,,	69	,,	6	,,
6000 ,,	68	,,	6	,,

Above the clouds the degree of humidity

At 7000 feet was	64	from	7	experiments.
8000 ,,	58	,,	7	,,
9000 ,,	52	,,	7	,,
10,000 ,,	52	,,	7	,,
11,000 ,,	48	,,	5	,,
12,000 ,,	48	,,	5	,,
13,000 ,,	43	,,	5	,,
14,000 ,,	58	,,	2	,,
15,000 ,,	53	,,	3	,,
16,000 ,,	45	,,	3	,,
17,000 ,,	33	,,	3	,,
18,000 ,,	21	,,	2	,,
19,000 ,,	36	,,	2	,,
20,000 ,,	33	,,	1	,,
21,000 ,,	32	,,	1	,,
22,000 ,,	21	,,	1	,,
23,000 ,,	16	,,	1	,,
24,000	unknown.			
25,000				
26,000				
27,000				
28,000				
29,000				

The laws of moisture here indicate a humidity on the ground, with a partially clear sky, less by 15 than in cloudy skies, increasing to 77 by 3000 feet, then nearly constant to 5000 feet, when the humidity abruptly decreased to 69, and then nearly evenly at the rate of 5 in 1000 feet, till at 9000 and 10,000 feet it is 52; the degree then constantly decreases, till at heights exceeding 25,000 feet the degree of humidity is reduced to less than 10; and it would seem that at the higher elevations there is an almost entire absence of water.

These seem to be the general laws; but this regular diminution is evidently often interrupted, and strata of moist air exist at different elevations even up to 20,000 feet, and these may be of considerable thickness.

§ 7. COMPARISON OF THE TEMPERATURE OF THE DEW-POINT, AS DETERMINED BY DIFFERENT INSTRUMENTS.

Every simultaneous or nearly simultaneous determination of the dew-point by the different instruments or methods was copied out, and then all those determinations between every 1000 feet of elevation were collected together, and in this way the first five columns of the following Table were formed. The numbers in the last six columns were formed by taking the differences between the temperatures of the respective dew-points in the same horizontal line, or those taken at about the same height and elevation.

TABLE IX.—Showing the Temperature of the Dew-point, as determined at about the same height by different instruments and methods, and comparison of the results together.

Under 1000 feet.

Date.	Height.	Dew-point Temperatures				Temperature of the Dew-point as determined by					
		Calculated from		Observed by		Dry and Wet (free) above that by			Dry and Wet (aspirated) above that by		Daniell's Hygrometer above that by Regnault's.
		Dry and Wet (free).	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.	Daniell's Hygrometer.	Regnault's Hygrometer.	
d h m	feet.	°	°	°	°	°	°	°	°	°	°
July 30 4 36	250	50·0		50·0			0·0				
4 42½	890	44·9		44·0			+0·9				
Aug. 18 0 56	490	55·0	54·6	55·0	53·9	+0·4	0·0	+1·1	−0·4	+0·7	+1·1
20 6 5	250	56·7		55·5			+1·2				
Sept. 1 4 40	250	56·5		52·0			+4·5				
4 53	320	51·9		52·0			−0·1				
5 0 0	490	49·5	49·9	49·0	45·5	−0·4	+0·5	+4·0	+0·9	+4·4	+3·5
8 5 43	887	59·9		58·5			+1·4				

Between 1000 and 2000 feet.

Date.	Height.	Dry and Wet (free).	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.	Daniell's Hygrometer.	Regnault's Hygrometer.	Daniell's Hygrometer above that by Regnault's.
Aug. 20 6 33	1497	51·3	..	52·1	..	..	−0·8				
7 16½	1871	49·3	..	49·0	..	..	+0·3				
7 19⅛	1367	50·3	..	50·5	..	..	−0·2				
7 24	1907	50·5	..	49·0	..	..	+1·5				
Sept. 1 5 59	1620	47·8	..	50·0	..	..	−2·2				
7 2	1567	49·0	..	47·5	..	..	+1·5				
8 5 35½	1420	56·6	..	55·0	..	..	+1·6				

TABLE IX. (*continued.*)

Between 2000 and 3000 feet.

Date.			Height.	Dew-point Temperatures				Temperature of the Dew-point as determined by					
				Calculated from		Observed by		Dry and Wet (free) above that by			Dry and Wet (aspirated) above that by		Daniell's Hygrometer above that by Regnault's.
				Dry and Wet (free).	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.	Daniell's Hygrometer.	Regnault's Hygrometer.	
d	h	m	feet.		°	°	°	°	°	°	°	°	°
July 30	4	45½	2379	42·6	..	38·5	..	..	+4·1				
	6	25	2700	42·2	..	42·5	..	..	−0·3				
Aug. 18	1	7	2042	52·5	50·6	..	48·5	+1·9	..	+4·0	..	+2·1	
20	6	35½	2257	50·0	..	51·5	..	..	−1·5				
	6	37½	2959	48·8	..	48·5	..	..	+0·3				
Sept. 1	4	55	2214	48·1	..	45·1	..	..	+3·0				
	4	58½	2940	44·0	..	47·8	..	..	−3·8				
	5	44	2910	42·2	..	41·5	..	..	+0·7				
	5	53	2446	43·7	..	43·5	..	..	+0·2				
	5	57	2190	47·1	..	46·0	..	..	+1·1				
	6	4	2057	48·9	..	48·0	..	..	+0·9				
8	6	0⅛	2034	57·1	..	56·5	..	..	+0·6				

Between 3000 and 4000 feet.

July 30	4	50½	3690	41·0	..	36·3	..	..	+4·7				
	4	52	3770	39·7	..	40·5	..	..	−0·8				
	4	52½	3790	40·7	..	41·5	..	..	−0·8				
Aug. 18	1	46	3438	..	..	47·8	47·2	..	..	..	..	..	+0·6
20	6	38	3159	48·9	..	48·0	..	..	+0·9				
	6	41	3816	46·6	..	44·2	..	..	+2·4				
	6	50	3893	44·9	..	44·5	..	..	+0·4				
	6	51½	3693	44·9	..	44·5	..	..	+0·4				
	6	52	3593	44·9	..	44·0	..	..	+0·9				
	6	55	3663	45·1	..	44·0	..	..	+1·1				
	6	56	3693	45·4	..	43·5	..	..	+1·9				
	6	58	3793	44·4	..	43·5	..	..	+0·9				
	7	2	3893	44·7	..	43·0	..	..	+1·7				
	7	10	3405	44·7	..	42·5	..	..	+2·2				
	7	13	3468	45·3	..	45·0	..	..	+0·3				
Sept. 1	5	1	3080	42·8	..	43·0	..	..	−0·2				
	5	3	3257	43·3	..	43·5	..	..	−0·2				
	5	8	3458	38·5	..	38·5	..	..	0·0				
	5	13	3680	37·8	..	38·5	..	..	−0·7				
	5	16	3620	38·4	..	38·4	..	..	0·0				
	5	19	3590	37·0	..	35·0	..	..	+2·0				
	5	20	3583	37·3	..	33·1	..	..	+4·2				
	5	24	3987	36·6	..	35·0	..	..	+1·6				
	5	28	3787	36·6	..	33·0	..	..	+3·6				
	5	37½	3690	37·2	..	37·5	..	..	−0·3				
	5	40	3362	38·4	..	38·0	..	..	+0·4				
5	1	10	3660	41·2	41·3	..	42·0	−0·1	..	−0·8	..	−0·7	

TABLE IX. (*continued.*)

Between 4000 and 5000 feet.

Date.			Height.	Dew-point Temperatures				Temperature of the Dew-point as determined by					
				Calculated from		Observed by		Dry and Wet (free) above that by			Dry and Wet (aspirated) above that by		Daniell's Hygrometer above that by Regnault's.
				Dry and Wet (free).	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.	Daniell's Hygrometer.	Regnault's Hygrometer.	
d	h	m	feet.	°	°	°	°	°	°	°	°	°	°
July 30	4	56	4169	40·3	..	41·5	..	..	−1·2				
	4	56½	4279	39·7	..	41·2	..	..	−1·5				
	5	1½	4104	40·2	..	43·1	..	..	−2·9				
	5	3	4324	40·7	..	43·1	..	..	−2·4				
	5	4½	4403	39·8	..	41·0	..	..	−1·2				
	5	7½	4613	36·5	..	40·5	..	..	−4·0				
	5	9½	4683	38·1	..	39·5	..	..	−1·4				
	5	14	4863	37·3	..	39·5	..	..	−2·2				
	5	16	4873	38·0	..	39·0	..	..	−1·0				
	5	16½	4923	37·6	..	39·5	..	..	−1·9				
	6	21	4950	37·0	..	39·0	..	..	−2·0				
	6	22	4450	38·8	..	40·0	..	..	−1·2				
Aug. 20	6	42	4116	45·9	..	44·2	..	..	+1·7				
	6	48	4316	43·8	..	44·5	..	..	−0·7				
	6	49	4116	45·7	..	44·5	..	..	+1·2				
	6	49½	4055	46·4	..	45·0	..	..	+1·4				
	7	5	4250	43·8	..	43·0	..	..	+0·8				
	7	7	4384	43·0	..	44·0	..	..	−1·0				
	7	8	4354	43·7	..	43·5	..	..	+0·2				
Sept. 1	5	31	4090	36·4	..	35·5	..	..	+0·9				
	5	33	4190	36·1	..	34·0	..	..	+2·1				
5	1	11½	4388	..	39·3	..	38·5	..	..	..	..	+0·8	
8	5	25	4829	45·7	..	43·0	..	..	+2·7				

Between 5000 and 6000 feet.

July 17	9	51	5802	33·8	..	30·5	..	..	+3·3				
30	5	18	5220	37·3	..	39·0	..	..	−1·7				
	5	21	5360	37·2	..	40·5	..	..	−3·3				
	5	22	5200	38·9	..	40·0	..	..	−1·1				
	5	23½	5200	37·2	..	42·0	..	..	−4·8				
	5	24	5330	38·7	..	40·2	..	..	−1·5				
	5	24½	5450	35·9	..	38·0	..	..	−2·1				
	5	26	5830	35·8	..	38·2	..	..	−2·4				
	5	28½	5530	35·4	..	36·2	..	..	−0·8				
	5	31½	5280	38·4	..	36·5	..	..	+1·9				
	5	39	5983	35·8	..	38·0	..	..	−2·2				
	5	47	5577	36·4	..	36·0	..	..	+0·4				
	5	50	5846	34·7	..	35·5	..	..	−0·8				
Aug. 18	1	38	5820	44·6	..	..	37·5	..	..	+7·1			
	1	55	5019	44·5	..	42·0	..	..	+2·5				
Sept. 5	1	13	5675	36·5	..	38·0	..	..	−1·5				
8	5	17½	5230	38·0	..	42·0	..	..	−4·0				

TABLE IX. (*continued.*)

Between 6000 and 7000 feet.

Date.			Height.	Dew-point Temperatures				Temperature of the Dew-point as determined by					
				Calculated from		Observed by		Dry and Wet (free) above that by			Dry and Wet (aspirated) above that by		Daniell's Hygrometer above that by Regnault's.
				Dry and Wet (free).	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.	Daniell's Hygrometer.	Regnault's Hygrometer.	
d	h	m	feet.	°	°	°	°	°	°	°	°	°	°
July 30	5	41	6370	34·0	..	36·0	..	..	−2·0				
	5	43	6370	32·7	..	34·0	..	..	−1·3				
	5	52	6102	33·1	..	36·0	..	..	−2·9				
	6	0	6937	30·3	..	32·0	..	..	−1·7				
	6	1	6867	32·0	..	31·5	..	..	+0·5				
	6	2	6547	31·4	..	32·0	..	..	−0·6				
	6	11⅓	6937	30·0	..	32·0	..	..	−2·0				
	6	13	6917	30·0	..	32·0	..	..	−2·0				
	6	14	..	30·8	..	31·8	..	..	−1·0				
	6	18	6400	32·7	..	31·0	..	..	+1·7				
	6	18½	6000	32·8	..	32·0	..	..	+0·8				
Sept. 5	1	17	6914	..	36·0	..	35·5	..	..	..	..	+0·5	

Between 7000 and 8000 feet.

Aug. 18	1	27	7836	41·8	..	..	34·0	..	..	+7·8			
	1	32	7650	40·6	..	35·5	35·0	..	+5·1	+5·6	..	..	+0·5
	1	33	7650	42·0	..	..	36·6	..	..	+5·4			

Between 8000 and 9000 feet.

July 17	9	55	8809	19·7	..	..	24·0	..	..	−4·3			
Aug. 18	2	11¾	8771	..	36·7	..	38·5	..	..	..	..	−1·8	

Between 9000 and 10,000 feet.

July 17	11	40	9882	19·9	19·7	..	..	+0·2					
Aug. 18	1	18¾	9954	29·2	..	30±	..	..	−0·8				
	1	24	9884	..	29·9	24·0	..	..	..	..	+5·9		

Between 10,000 and 11,000 feet.

Aug. 18	1	22	10840	28·6	..	22·0	25·0	..	+6·6	+3·6	..	..	−3·0
	2	17	10864	27·4	31·0	..	29·5	−3·6	..	−2·1	..	+1·5	
Sept. 5	1	22	10774	28·9	..	..	25·0	..	..	+3·9			

TABLE IX. (*continued.*)

Between 11,000 and 12,000 feet.

Date.	Height.	Dew-point Temperatures				Temperature of the Dew-point as determined by					
		Calculated from		Observed by		Dry and Wet (free) above that by			Dry and Wet (aspirated) above that by		Daniell's Hygrometer above that by Regnault's.
		Dry and Wet (free).	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.	Daniell's Hygrometer.	Regnault's Hygrometer.	
d h m	feet.	°	°	°	°	°	°	°	°	°	°
July 17 10 2	11792	23·9	..	..	25·0	..	..	−1·1			

Between 12,000 and 13,000 feet.

July 17 10 3	12709	..	..	19·5	21·0	..	..	..	..	..	−1·5
Aug. 18 2 21	12364	22·2	22·2	..	29·0	0·0	..	..	..	− 6·8	
3 36	12453	12·6	..	..	14·0	..	..	−1·4			
Sept. 5 1 24	12568	..	14·5	..	(25·0)	..	..	..	..	−10·5	

Between 13,000 and 14,000 feet.

July 17 10 4	13000	16·9	..	21·0	22·0	..	−4·1	−5·1	..	..	−1·0
10 5	13467	24·9	..	..	22·5	..	..	+2·4			
Aug. 18 3 34	13320	..	9·8	..	12·5	..	..	..	..	−2·7	

Between 14,000 and 15,000 feet.

July 17 10 8	14544	24·0	26·7	20·5	24·0	−2·7	+3·5	0·0	+6·2	+2·7	−3·5

Between 15,000 and 16,000 feet.

July 17 10 11	15704	24·6	22·7	22·0	21·5	+1·9	+2·6	+3·3	+0·7	+1·4	+0·7

Between 16,000 and 17,000 feet.

July 17 10 15	16914	24·3	19·8	23·0	20·8	+4·5	+1·3	+3·5	−3·2	−1·0	+2·2
Aug. 18 2 31	....	..	−0·7	..	6·0	..	..	..	..	−6·7	

Between 17,000 and 18,000 feet.

Aug. 18 2 32½	....	18·8	..	−1·4	..	..	+20·2				
2 34½	....	24·0	..	..	3·5	..	..	+20·5			

Between 18,000 and 19,000 feet.

July 17 10 25	18844	24·9	24·4	25·1	24·2	+0·5	−0·2	+0·7	−0·7	+0·2	+0·9
Aug. 18 2 35	18039	..	− 5·4	..	3·0	..	..	..	..	−8·4	
2 36	....	..	−11·5	..	0·0	..	..	..	..	−11·5	

TABLE IX. (*continued.*)

Between 19,000 and 20,000 feet.

Date.	Height.	Dew-point Temperatures				Temperature of the Dew-point as determined by					
		Calculated from		Observed by		Dry and Wet (free) above that by			Dry and Wet (aspirated) above that by		Daniell's Hygrometer above that by Regnault's.
		Dry and Wet (free).	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.	Daniell's Hygrometer.	Regnault's Hygrometer.	
d h m	feet.	°	°	°	°	°	°	°	°	°	°
July 17 10 27	19374	25·6	23·2	22·6	21·0	+2·4	+3·0	+4·6	+0·6	+2·2	+1·6
10 29	19415	19·5	21·4	..	22·2	−1·9	..	−2·7	..	−0·8	
10 30	19415	21·8	18·3	21·5	22·2	+3·5	+0·3	−0·4	−3·2	−3·9	−0·7
10 35	19548	16·6	..	19·0	20·0	..	−2·4	−3·4	..	..	−1·0
10 39	19380	23·8	..	20·0	21·1	..	+3·8	+2·7	..	..	−1·1
10 44	19336	22·1	22·1	20·5	20·5	0·0	+1·6	+1·6	+1·6	+1·6	0·0
Sept. 5 1 37¾	19000+	−13·0	..	−10·0	..	..	−3·0				

Between 20,000 and 21,000 feet.

Sept. 5 1 40½	20000+	−8·2	..	..	−15·0	..	..	+6·8			

By taking the mean of each column of differences in each 1000 feet of elevation, the next Table is formed.

TABLE X.—Showing the mean differences between the Temperatures of the Dew-point as found by the use of the Dry- and Wet-bulb Thermometers and by Daniell's and Regnault's Hygrometers, and comparison of the results as found from the two Hygrometers.

Heights between	Excess of Temperature of the Dew-point as found by										
	Dry and Wet Thermometers (free) above that found by						Dry and Wet (aspirated) above that found by				Daniell's Hygr. above that by
	Dry and Wet Bulbs (aspirated).	No. of obs.	Daniell's Hygrometer.	No. of obs.	Regnault's Hygrometer.	No. of obs.	Daniell's Hygrometer.	No. of obs.	Regnault's Hygrometer.	No. of obs.	Regnault's Hygrometer.	No. of obs.
feet. feet.	°		°		°		°		°		°	
0 to 1000	0·0	2	+1·1	8	+2·6	2	+0·2	2	+2·6	2	+2·3	2
1000 ,, 2000	...	...	+0·2	7								
2000 ,, 3000	+1·9	1	+0·5	11	+4·0	1	...	...	+2·1	1		
3000 ,, 4000	−0·1	1	+1·1	25	...	...	...	...	−0·7	1	+0·6	1
4000 ,, 5000	...	...	−0·6	22	...	...	...	...	+0·8	1		
5000 ,, 6000	...	...	−1·2	16	+7·1	1						
6000 ,, 7000	...	...	−0·9	11	...	...	...	...	+0·5	1		
7000 ,, 8000	...	...	+5·1	1	+6·3	3	...	...	...	...	+0·5	1
8000 ,, 9000	...	...	...	...	−4·3	1	...	...	−1·8	1		
9000 ,, 10000	+0·2	1	−0·8	1	...	...	+5·9	1				
10000 ,, 11000	−3·6	1	+6·6	1	−1·8	3	...	...	+1·5	1	−3·0	1
11000 ,, 12000	...	...	...	..	−1·1	1						
12000 ,, 13000	0·0	1	...	...	−1·4	1	...	...	−8·6	2	−1·5	1
13000 ,, 14000	...	...	−4·1	1	−1·3	2	...	...	−2·7	1	−1·0	1
14000 ,, 15000	−2·7	1	+3·5	1	0·0	1	+6·2	1	+2·7	1	−3·5	1
15000 ,, 16000	+1·9	1	+2·6	1	+3·3	1	+0·7	1	+1·4	1	+0·7	1
16000 ,, 17000	+4·5	1	+1·3	1	+3·5	1	−3·2	1	−3·9	2	+2·2	1
17000 ,, 18000												
18000 ,, 19000	+0·5	1	−0·2	1	+0·7	1	−0·7	1	−6·6	3	+0·9	1
19000 ,, 20000	+1·0	4	+0·5	6	+0·4	6	−0·3	3	−0·2	4	−0·2	5

The numbers in every one of these columns are affected with a change of sign, and, therefore, no certain difference is shown over the determination of the dew-point as found by any method or instrument over that found by any other.

By taking the means of all in each group of 5000 feet, giving weight according to the number of experiments upon which each result is based, we have:—

From the ground to 5000 feet high the temperature of the dew-point as determined by—

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Dry and Wet bulb (free)

Experiments.
Was 0°·4 higher than as found by Dry and Wet (aspirated) . . from 4
„ the same as found by Daniell's Hygrometer . . . . „ 73
„ 2°·2 higher than as found by Regnault's Hygrometer . . „ 3

Dry and Wet bulb (aspirated)
Was 0°·1 higher than as found by Daniell's Hygrometer . . . . „ 2
„ 1°·0 „ „ „ Regnault's „ . . . . „ 5

Daniell's Hygrometer
Was 1°·0 higher than as found by Regnault's Hygrometer . . „ 3

From 5000 feet to 10,000 feet the temperature of the dew-point as determined by
Dry and Wet (free)
Was 0°·2 higher than as found by Dry and Wet (aspirated) . . from 1
„ 0°·1 „ „ „ Daniell's Hygrometer . . . . „ 29
„ 1°·8 „ „ „ Regnault's „ . . . . „ 5

Dry and Wet (aspirated)
Was 5°·9 higher than as found by Daniell's Hygrometer . . . . „ 2
„ 0°·7 lower „ „ Regnault's „ . . . . „ 1

From 10,000 to 15,000 feet the temperature of the dew-point as determined by
Dry and Wet (free)
Was 2°·1 lower than as found by Dry and Wet (aspirated) . . from 3
„ 2°·0 higher „ „ Daniell's Hygrometer . . . . . . „ 3
„ 0°·7 lower „ „ Regnault's „ . . . . . . „ 8

Dry and Wet (aspirated)
Was 6°·2 higher than as found by Daniell's Hygrometer . . . . „ 1
„ 1°·4 lower „ „ Regnault's „ . . . . „ 5

Daniell's Hygrometer
Was 2°·2 lower than as found by Regnault's Hygrometer . . . . „ 4

From 15,000 to 20,000 feet the temperature of the dew-point as determined by

Dry and Wet (free)

		Experiments.
Was 1°·1 higher than as found by	Dry and Wet (aspirated) . . from	7
,, 0°·5 ,, ,, ,,	Daniell's Hygrometer . . . . ,,	9
,, 0°·9 ,, ,, ,,	Regnault's ,, ... ,,	9

Dry and Wet (aspirated)

Was 0°·6 lower than as found by	Daniell's Hygrometer. . . . . . ,,	6
,, 0°·9 ,, ,, ,,	Regnault's ,, ... ,,	10

Daniell's Hygrometer

Was 0·4 higher than as found by	Regnault's Hygrometer. . . . ,,	8

By taking the mean of all, according to the number of experiments, we have:—

From the ground to 20,000 feet the mean temperature of the dew-point as found by

Dry and Wet (free)

Was 0°·2 higher than as found by	Dry and Wet (aspirated) . . from	15
,, 0°·1 ,, ,, ,,	Daniell's Hygrometer . . . . ,,	114
,, 0°·7 ,, ,, ,,	Regnault's ,, ... ,,	25

Dry and Wet (aspirated)

Was 0°·9 higher than as found by	Daniell's Hygrometer . . . . ,,	10
,, 0°·6 lower ,, ,,	Regnault's ,, ... ,,	22

Daniell's Hygrometer

Was 0°·1 lower than as found by	Regnault's Hygrometer . . ,,	16

From all the results it would seem that the temperature of the dew-point as deduced from the Dry- and Wet-bulb thermometers as ordinarily used has a tendency to give a result a little too high, but to an amount that is less than the probable error of observations, and that, therefore, it is a perfectly trustworthy instrument to use, even to great altitudes; also, the results by Daniell's Hygrometer seem to be of equal value with those found by Regnault's Hygrometer, at all elevations.

§ 8. COMPARISON OF THE READINGS OF THE MERCURIAL AND ANEROID BAROMETERS AT DIFFERENT HEIGHTS.

All the simultaneous readings of the Siphon and Aneroid Barometers were extracted from Table I. and inserted in the following Table.

TABLE XI.—Comparison of the Readings of Mercurial and Aneroid Barometers, in the ascents on July 17 and August 18.

Month, day, hour and minute.				Readings of Barometers.		Excess of Reading of Aneroid above Siphon Barometer.	Month, day, hour and minute.				Readings of Barometers.		Excess of Reading of Aneroid above Siphon Barometer.
				Siphon.	Aneroid.						Siphon.	Aneroid.	
	h	m	s	in.	in.	in.		h	m	s	in.	in.	in.
July 17,	9	49	0	25·22	25·32	+0·10	Aug. 18,	0	56	0	29·34	29·51	+0·17
	9	51	0	24·14	24·30	+0·16		1	6	0	28·55	28·78	+0·23
	9	53	0	22·42	22·65	+0·23		1	8	0	26·67	26·90	+0·23
	9	54	0	22·02	22·20	+0·18		1	10	0	25·86	26·08	+0·22
	9	55	0	21·58	21·80	+0·22		1	14	0	23·64	23·82	+0·18
	9	56	0	20·93	21·10	+0·17		1	15	0	22·69	22·68	−0·01
	9	58	0	19·63	20·09	+0·46		1	20	0	19·90	20·05	+0·15
	10	2	0	19·28	19·60	+0·32		1	24	15	20·90	21·28	+0·38
	10	3	0	18·63	18·90	+0·27		1	27	0	22·62	22·90	+0·28
	10	5	0	18·14	18·40	+0·26		1	32	0	22·80	22·85	+0·05
	10	8	0	17·24	17·52	+0·28		1	38	0	24·46	24·60	+0·14
	10	11	0	16·74	17·10	+0·36		1	41	0	25·08	25·30	+0·22
	10	15	0	16·04	16·25	+0·21		1	52	0	25·80	25·82	+0·02
	10	25	0	14·94	15·15	+0·21		1	55	0	25·08	25·25	+0·17
	10	27	0	14·64	15·30	+0·66		2	0	0	23·93	24·10	+0·17
	10	29	0	14·64	15·30	+0·66		2	9	0	22·58	22·71	+0·13
	10	30	0	14·64	15·30	+0·66		2	17	0	20·24	20·50	+0·26
	10	35	0	14·64	15·00	+0·36		2	21	0	19·11	19·30	+0·19
	10	44	0	14·63	15·10	+0·47		2	25	20	17·61	17·85	+0·24
	10	47	0	14·13	14·70	+0·57		2	29	0	16·41	16·50	+0·09
	10	50	0	13·64	14·20	+0·56		2	32	20	15·84	16·00	+0·16
	10	54	0	13·14	13·60	+0·46		2	49	50	13·70	13·60	−0·10
	10	57	0	12·14	12·60	+0·46		3	5	0	12·93	13·20	+0·27
	11	3	0	11·64	12·10	+0·46		3	18	30	13·45	13·55	+0·10
	11	7	0	11·65	12·10	+0·45		3	25	0	13·65	13·72	+0·07
	11	12	0	11·95	12·40	+0·45		3	34	+	17·53	17·42	−0·11
	11	20	0	12·65	13·20	+0·55		3	36	0	18·63	18·65	+0·02
	11	25	0	13·14	13·60	+0·46		3	39	0	20·02	20·05	+0·03
	11	38	0	18·94	19·00	+0·06		3	49	0	24·28	24·42	+0·14
	11	39	0	20·04	20·40	+0·36							
	11	40	0	20·54	20·80	+0·26							

July 17.—The differences between the readings are shown in the last column, and exhibit an increasing difference, increasing in amount with decreasing readings, till at the highest point the discordance between the readings amounted to half an inch. It is presumed that the aneroid barometer was in error to these amounts; but both instruments were broken in the descent, and no more information can be given.

August 18.—The differences between the readings of the mercurial and aneroid barometers in this ascent were as constant as could be expected, as the readings could seldom be strictly simultaneous. Upon the whole, the readings of the aneroid are as good as those of the siphon.

Table XI. (*continued*).—Comparison of the Readings of Mercurial and Aneroid Barometers and Negretti's new Barometer, in the Ascent on September 5.

Month, day, hour and minute.	Readings of Barometers.			Excess of Reading of Aneroid above Siphon Barometer.	Excess of Reading above Negretti's new Barometer	
	Siphon.	Aneroid.	Negretti's new Barometer.		of Siphon Barometer.	of Aneroid Barometer.
h m s	in.	in.	in.	in.	in.	in.
Sept. 5, 0 0 0	29·40	29·40	......	0·00		
1 5 10	28·97	29·10	......	+0·13		
1 5 30	28·57	28·60	28·72	+0·03	−0·15	−0·12
1 6 0	28·38	28·35	28·55	−0·03	−0·17	−0·20
1 10 0	26·19	26·20	26·35	+0·01	−0·16	−0·15
1 11 30	25·49	25·62	......	+0·13		
1 13 0	24·30	24·45	24·60	+0·15	−0·30	−0·15
1 14 30	23·70	23·90	23·90	+0·20	−0·20	0·00
1 16 0	23·36	23·40	......	+0·04		
1 17 40	22·66	22·71	22·75	+0·05	−0·09	−0·04
1 21 0	20·72	20·60	20·65	−0·12	+0·07	−0·05
1 22 0	20·07	20·17	......	+0·10		
1 25 30	17·93	18·10	17·90	+0·17	+0·03	+0·20
1 27 0	16·94	16·90	16·90	−0·04	+0·04	0·00
1 28 0	16·69	16·65	......	−0·04		
1 35 0	14·65	14·90	......	+0·25		
1 36 0	14·55	14·80	......	+0·25		
1 37 30	14·47	14·80	......	+0·33		
2 8 30	12·55	12·80	......	+0·25		
2 9 30	16·37	16·45	16·50	+0·08	−0·13	−0·05
2 9 40	17·07	......	17·20	....	−0·13	
2 11 0	17·71	......	17·85	....	−0·14	
2 16 10	19·75	19·90	19·90	+0·15	−0·15	0·00
2 16 20	20·05	20·25	20·25	+0·20	−0·20	0·00
2 16 50	20·65	20·65	20·70	0·00	−0·05	−0·05
2 17 30	21·15	21·55	21·30	+0·40	−0·15	+0·25
2 19 30	21·85	21·90	21·90	+0·05	−0·05	0·00
2 20 20	22·04	......	22·00	....	+0·04	
2 20 40	22·24	22·20	22·45	−0·04	−0·21	−0·25
2 23 20	22·64	22·76	22·70	+0·12	−0·06	+0·06
2 23 50	22·93	23·20	23·00	+0·27	−0·07	+0·20
2 24 0	23·03	23·00	22·95	−0·03	+0·08	+0·05
2 32 0	25·40	25·55	25·30	+0·15	+0·10	+0·25
2 38 0	26·40	26·35	26·35	−0·05	+0·05	0·00
3 6 0	......	29·02	29·20	....	....	−0·18

The numbers in the last column but two show the differences between the readings of the siphon and aneroid barometers, those in the last column but one the differences between the readings of the siphon barometer and Negretti and Zambra's new barometer, and those in the last column the differences between the readings of the aneroid barometer and Negretti and Zambra's new barometer; these several differences are all small, and are within the probable error of observation, as it is not possible that the readings can be made at the same instant. They prove that all the observations made in the several ascents may safely be depended upon, and also that an aneroid barometer can be made to read correctly to pressures below 12 inches.

§ 9. ELECTRICAL STATE OF THE ATMOSPHERE.

In the ascent on July 17, an electrometer, kindly lent by Professor W. Thomson, of Glasgow, was used. Care (according to the instructions from Professor Thomson) was taken to discharge the electricity from the balloon on leaving the earth, and a charge of negative electricity was given to the instrument, and it read 59°, which we may call the balloon-reading. The instrument leaked a little, and it was necessary at every experiment to redetermine the balloon-reading. The following are the results of the observations:—

At 13,500 feet..	Balloon-reading	59°
	Electricity of the air ..	64
At 14,500 feet..	Balloon-reading	59
	Electricity of the air ..	63
At 15,700 feet..	Balloon-reading	59
	Electricity of the air ..	63
At 19,500 feet..	Balloon-reading	58
	Electricity of the air ..	61
At 19,300 feet..	Balloon-reading	58
	Electricity of the air ..	60¼
At 23,000 feet..	Balloon-reading	58
	Electricity of the air ..	58+

Now as these observations were made under the balloon, and the readings for the air were large negative readings always, it implies that the air was charged with positive electricity, but becoming less and less in amount with increasing elevation, till at the height of 23,000 feet the amount was too small to measure but was of the same kind. It is impossible therefore to say whether at higher elevations there would have been no electricity, or whether it would have changed to negative. I wish, however, to speak guardedly on this subject, and would regard these observations as indications only. I pledge myself no further than that all the directions given to me by Professor Thomson were followed, and that the readings are correct.

ON THE OXYGENIC CONDITION OF THE ATMOSPHERE.

On July 17th the test papers, both by Moffat and Schönbein, continued untinged by colour throughout the whole flight of the balloon, and the same result was found during the ascent on July 30.

After these ascents I received the following letter from Dr. Moffat:—

"Hawarden, August 4th, 1862.

DEAR MR. GLAISHER,

"In the *Times* of Saturday last I observed, in your report of meteorological observations taken during a balloon ascent from the Crystal Palace on July 30th, that 'test ozone papers were not coloured, and no ozone was noticed in the ascent from Wolverhampton.' This is remarkable, seeing that ozone increases in quantity directly with increase of elevation on the earth's surface. The degree of coloration of test papers varies with the humidity of the atmosphere. Dry air retards the decomposition of the iodine of potassium, and very moist air removes the iodine when decomposition has taken place. It does not appear, however, in the observations, that the degree of humidity on the day of ascent was in any way unfavourable to the decomposition of the iodine, or the development of the brown colour on the test papers.

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"The time the balloon was up was short (two hours), and ozone must be in very considerable quantity to produce coloration of the test paper in so short a period of time. Still, according to our present notions of increase of the quantity of ozone with increase of elevation, papers of ordinary sensitiveness ought to have been coloured during the ascents. The sensitiveness of the papers used in the investigation is of course of the utmost importance.

"Today the quantity of ozone indicated by test papers prepared by myself is 4; and two papers from a packet prepared by Messrs. Negretti and Zambra, exposed for *two hours in sunshine*, did not show the slightest tinge, while a slip prepared by myself, exposed under similar circumstances, gave a degree of coloration equal to the mean of the day. From these results it would appear that the test papers used by you were in fault. This is a question of some moment, and one of great scientific interest; and if future balloon ascents give results similar to those you have reported, then the ground of the *development* of ozone must be looked for in the atmosphere near the surface of the earth.

"I am, yours very truly,
"*Jas. Glaisher, Esq.*" (Signed) "T. MOFFAT."

In consequence of the receipt of this letter I went to Hawarden to Dr. Moffat, and induced him to make some test papers himself for the balloon experiments. He did so, and they were used on August 18th. I took some of the papers prepared by him, and some of the papers out of the same packets which I had used during the two preceding ascents, as well as some prepared by a formula of Schönbein. When I had reached 10,000 feet the new papers were decidedly tinged; at 17,000 feet they were coloured to the amount of 2, on a scale whose deepest colour is represented by 10; at 20,000 feet to 3. At 22,000 feet the coloration had increased to 4; and here Schönbein's paper was coloured to 1, and Moffat's old papers were still uncoloured. Moffat's new papers gradually increased in intensity, and when 3000 feet from the earth at $2^{h}\,38^{m}$ were deepened to 7. It would therefore appear that in all probability the test papers were in fault in the first ascents; and I may here remark that, in consequence, the preparation of the ozone test papers has been stopped, and that it is my intention, as Dr. Moffat himself cannot undertake the task, to superintend the preparation of the papers myself in future.

TIME OF VIBRATION OF A MAGNET.

On July 17, at Wolverhampton, there were

		s.		s.
30	vibrations of a magnet in	42·1;	that is, one vibration in	1·403
30	,, ,,	42·5;	,, ,,	1·417
30	,, ,,	42·4;	,, ,,	1·413

Therefore one vibration =1·411 second.

At the height of 18,844 feet one vibration = $1^{s}{\cdot}489$.
At the height of 20,244 feet one vibration = $1^{s}{\cdot}536$.

Therefore the time of vibration seemed to be somewhat longer.

On July 30, at the Royal Observatory, Greenwich, the time of the vibration of the magnet =1·573 second.

On July 30, the mean of four sets of observations at the mean height of 5300 feet gave

One vibration $=1^{s}{\cdot}572$,

being sensibly the same as the result on the same day as determined at the Observatory.

On August 18, at Wolverhampton,

		s.				s.
38	vibrations	=60·0	∴ one	vibration	=	1·580
32	„	50·3	„	„		1·572
34	„	54·2	„	„		1·595
30	„	47·9	„	„		1·597
						4)6·344
						1·586

Therefore one vibration=1·586 second.

At 11,000 feet 26 vibrations =41·5 second.
Therefore one vibration= 1·590 second.
A result differing but little from that on the ground.

August 20, at the Royal Observatory, Greenwich, the time of one vibration was 1·580 second.

August 20, at the height of 3800 feet one vibration =1·583 second.

On September 5, I did not succeed in getting the time of vibration of the magnet at all in the balloon. During this ascent we were almost constantly going round and round—a motion fatal to observations of this nature, and failure at all times was the rule in these experiments. I commenced many series of experiments with the axis of the car in one position relative to the cardinal points of the compass, which I found to be different before the observations were completed, and consequently the observations were of no value.

The general result of these experiments is that the magnet vibrates in a somewhat longer interval of time at high elevations than on the earth. The number of experiments, however, is too few to speak decidedly on this point.

HEIGHTS AND APPEARANCE OF THE CLOUDS.

July 17.

The sky was covered with cumulostratus clouds before starting.

At $9^h\ 47^m$ a.m., at 4467 feet. Clouds were reached.

At $9^h\ 51^m$ a.m., at 5802 feet. Many clouds all round at a lower elevation.

At $9^h\ 53^m$ a.m., at 7980 feet. Entered a dense cumulostratus cloud.

At $9^h\ 55^m$ a.m., at 9000 feet. Passed out of cloud into bright sunshine and blue sky

At $10^h\ 2^m$ a.m., at 11,792 feet. Examined the clouds below, which were noted as being very beautiful in form and arrangement.

At $10^h\ 15^m$ a.m., at 16,914 feet. Cumuli were underneath and far below; strati in the distance, apparently the same height as the eye. No clouds above: blue sky.

At $11^h\ 38^m$ a.m., at 12,376 feet. On descending the shadow of the balloon and car on the cloud below was very large and distinct; entered the cloud directly afterwards.

At $11^h\ 40^m$ A.M., at 9882 feet. In so dense a cloud that the balloon could not be seen.

At $11^h\ 45^m$ A.M., at 5432 feet. Came out of cloud, but passed through others which appeared to be rising with great rapidity.

July 30.

Partially clear before starting, there being cirrocumulus, cumulostratus, cirrostratus, and a little cirrus nearly covering the sky, but very thin in the zenith.

At 5h 26m p.m., at 5830 feet. Cumuli all round at lower elevations; zenith clear.

At 5h 54m p.m., at 6466 feet. A great mist, surrounding the balloon.

At 6h 2m p.m., at 6547 feet. Cumuli and cumulostratus were below.

At 6h 7m p.m., at 6600 feet. Cumuli and cumulostratus appeared at the same level with the car, and strati above.

August 18.

At 1h p.m. Zenith clear, wind W.N.W. but light, clouds moving N. by W.

At 1h 8m p.m., at 3347 feet. A cumulus cloud was entered.

At 1h 24m p.m., at 9884 feet. Detached cumuli far below; plains of clouds in the distance.

At 1h 27m p.m., at 7836 feet. Alpine and dome-like clouds, bright and even on one side, in shade and lumpy on the other; detached cumuli at a lower elevation.

At 1h 34m p.m., at 6000 feet. Clouds have a very beautiful appearance.

At 1h 58m 40s p.m., at 5800 feet. Cumuli apparently same height as the car in the distance.

At 2h 22m 30s p.m., at 12,700 feet. Great mass of clouds to the east.

At 2h 25m 20s p.m., at 14,300 feet. A sea of clouds; snow-white appearance; a few clouds below; cirri still much higher. A deep-blue sky.

For note on the appearance of the clouds at 3h 33m p.m., see Section of Observations, &c., p. 400.

At 3h 43m p.m., at 8144 feet. The shadow of the balloon and car on the cloud below very large and distinct.

At 3h 43m 30s p.m., at 7438 feet. Entered clouds.

At 3h 46m 10s p.m., at 6050 feet. In cloud, can see nothing; passed out of cloud at 6000 feet; a lower stratum of cloud.

At 3h 46m 30s p.m., at 5979 feet. Image of balloon on lower clouds magnificent.

At 3h 48m p.m., at 5922 feet. Entered a second stratum of cloud.

At 3h 49m p.m., at 5621 feet. Still in cloud.

At 3h 50m p.m., at 5300 feet. Emerged from the clouds.

At 3h 51m p.m., at 4520 feet. In thick mist.

At 3h 55m p.m., at 3000 ± feet. Passed out of mist.

August 20.

At 6h 30m p.m. Very hazy; cirri prevalent in zenith; cloudy elsewhere.

At 6h 32m 30s p.m., at 1397 feet. In a mist.

At 6h 38m p.m., at 3159 feet. Misty all round, detached scud beneath.

At 6h 39m p.m., at 3359 feet. Clouds below as scud.

At 6h 43m p.m., at 4256 feet. Clouds far below, but not under us.

At 6h 43m 30s p.m., at 4316 feet. Entered a cloud.

At 6h 58m p.m., at 3793 feet. Clouds were all below.

At 7h 5m p.m., at 4250 feet. In mist; earth invisible.

At 7h 25m p.m., at 2067 feet. Fog below.

At 7h 47m p.m., at 5194 feet. In cloud; London out of sight.

At 7h 49m p.m., at 5900 feet. Having passed above the clouds, their upper surfaces were of a rich red.

At 7^h 50^m p.m., at 5500 feet. In cloud.

At 7^h 52^m p.m., at 5200 feet. Above the clouds again.

At 7^h 55^m p.m., at 5500 feet. Setting sun tinged the clouds with red; a beautiful appearance.

At 7^h 56^m p.m., at 5160 feet. In cloud again.

At 8^h 5^m p.m., at 7000 feet. Above the clouds.

August 21.

The sky was overcast, being covered with dense cirrostratus clouds before starting.

At 4^h 40^m a.m., at 1210 feet. In a thick mist.

At 4^h 41^m a.m., at 1286 feet. Clouds broken; in the east there were beautiful lines of light, with gold and silver tints.

At 4^h 44^m a.m., at 1706 feet. Earth visible in the distance.

At 4^h 45^m a.m., at 2000 feet. Very misty; blocks of clouds above.

At 4^h 49^m a.m., at 2930 feet. Scud below, creeping along the earth; cumuli apparently on same level in the distance; black clouds above.

At 4^h 55^m a.m., at 4927 feet. Entered the clouds.

At 4^h 56^m a.m., at 5300 feet. Lost sight of earth.

At 4^h 57^m 30^s a.m., at 5989 feet. Great masses of alpine cloud; entered a beautiful cumulus cloud.

At 4^h 58^m a.m., at 6000 + feet. In cloud, surrounded by white mist.

At 5^h a.m., at 6510 feet. Emerged in a valley between two clouds.

At 5^h 1^m a.m., at 6400 ± feet. Immense ocean of cloud; magnificent view.

At 5^h 1^m 20^s a.m., at 6350 ± feet. Under the sun the appearance of a lake; mountains of clouds to the left; fine cloud-land generally.

At 5^h 3^m a.m., at 6336 feet. Lost sight of sun; misty.

At 5^h 4^m a.m., at 6413 feet. Deep ravines and shaded parts visible in the clouds; sun again rising in same magnificent way; clouds sweeping boldly away.

At 5^h 34^m 30^s a.m., at 13,875 feet. Magnificent peaks of cloud in the distance; like a sea of cotton.

At 5^h 48^m a.m., at 14,273 feet. Sea of clouds below.

At 5^h 51^m a.m., at 14,318 feet. Thin strati obscure the sun.

At 5^h 57^m a.m., at 14,228 feet. Strati apparently same height as ourselves; cirri above.

At 6^h a.m., at 14,213 feet. Beautiful sea of clouds everywhere.

At 6^h 24^m a.m., at 8040 feet. The shadow of the balloon on the clouds below was distinct, and surrounded by prismatic colours.

At 6^h 27^m a.m., at 7293 feet. Clouds approached on descending.

At 6^h 28^m 30^s a.m., at 7106 feet. In a mist.

At 6^h 29^m a.m., at 7001 feet. Just entering clouds.

At 6^h 35^m a.m., at 5189 feet. Stratum of cloud beneath.

At 6^h 36^m 30^s a.m., at 5058 feet. } Entered the clouds, and passed below
At 6^h 38^m ± a.m., at 4000 ± feet. } them.

September 1.

The sky was uniformly covered with cirrostratus clouds.

At 5^h 5^m 30^s p.m., at 3408 feet. Cumuli in horizon apparently at a low elevation.

At 5^h 16^m p.m., at 3620 feet. Apparently on a level with cumuli in the distance.

At 5^h 30^m p.m., at 4000 feet. Higher than all clouds near us.

At 5^h 31^m p.m., at 4090 feet. Clouds have formed over the river from the Nore up to beyond Richmond, following the river in all its windings and bendings, and almost confined to its banks throughout.

At 5^h 32^m p.m., at 4180 feet. Clouds far below, and moving apparently at right angles to our motion.

At 5^h 36^m p.m., at 4000 feet. Clouds meeting us, moving at right angles to our motion; clouds very low.

At 5^h 37^m p.m., at 3900 feet. Clouds passing quickly below us.

At 5^h 37^m 30^s p.m., at 3690 feet. Clouds still follow the course of the river, being limited to its breadth, and parallel to it throughout its course.

At 5^h 40^m p.m., at 3362 feet. Clouds meeting us of three different degrees of white: the top bluish white, the middle the pure white of the cumulus, and the lower blackish white; and from these, we afterwards learned, rain had been falling on the earth all the afternoon.

September 5.

The sky was covered with clouds before starting.

At 1^h 13^m 30^s p.m., at 5722 feet. In cloud, wholly obscured.

At 1^h 16^m p.m., at 6729 feet. Still in cloud, very dense.

At 1^h 17^m 20^s p.m., at 6914 feet. Out of cloud.

September 8.

At 4^h 48^m p.m. The sky was overcast, with cirrostratus clouds.

At 4^h 49^m p.m., at 1232 feet. Scud at lower elevation, but not under us.

At 4^h 54^m 30^s p.m., at 4169 feet. In mist, then in dense fog.

At 4^h 55^m p.m., at 4380 feet. In a dense white cloud.

At 4^h 56^m 30^s p.m., at 4650 feet. Still in cloud, thick and white.

At 4^h 58^m 20^s p.m., at 4750 feet. Half out of cloud; the crown of the balloon was out of cloud, and the car still within.

At 4^h 59^m 10^s p.m., at 4650 feet. Cloud more dense; balloon descending.

At 5^h 1^m 30^s p.m., at 4400 feet. Misty view; horizon obscured all round.

At 5^h 1^m 50^s p.m., at 4200 feet. Very black clouds over London.

At 5^h 7^m p.m., at 3370 feet. Beautiful break in the clouds to the west.

At 5^h 10^m 30^s p.m., at 4108 feet. In slight mist.

At 5^h 11^m 25^s p.m., at 4400 feet. Clouds below.

At 5^h 12^m 30^s p.m., at 4920 feet. The shadow of the balloon and car surrounded by primary and secondary prismatic rings.

At 5^h 14^m 40^s p.m., at 4920 feet. Clouds heaped upon each other, apparently on a level with the car.

At 5^h 16^m 45^s p.m., at 5260 feet. Fluffy clouds below.

At 5^h 17^m 30^s p.m., at 5230 feet. Clouds rising were whiter than those below; a slight amount of blue in all clouds.

At 5^h 17^m 55^s p.m., at 5428 feet. Balloon approaching clouds.

At 5^h 18^m 30^s p.m., at 5428 feet. The shadow of the balloon and car on clouds, encircled by three distinct prismatic rings.

At 5^h 20^m 30^s p.m., at 5112 feet. Clouds near us like smoke.

At 5^h 22^m p.m., at 5060 feet. Beautiful chasm in the clouds.

At 5^h 22^m p.m., at 5057 feet. Entering clouds.

At 5^h 22^m 45^s p.m., at 5040 feet. Just entering clouds.

At 5^h 24^m 10^s p.m., at 5020 feet. Entering clouds again.

At 5^h 24^m 30^s p.m., at 5039 feet. In cloud.

At 5^h 25^m 20^s p.m., at 4700 feet. Still in cloud.

At $5^h\ 26^m\ 25^s$ p.m., at 3220 feet. Cumuli below as scud.

At $5^h\ 27^m\ 30^s$ p.m., at 3600 feet. A fine white cloud apparently resting on the Thames, like a huge swan.

APPEARANCE OF THE SKY.

July 17.

At $10^h\ 15^m$ a.m., at 16,914 feet. Intense prussian blue.

At $10^h\ 39^m$ a.m., at 19,380 feet. Deep blue.

July 30.

At $5^h\ 31^m\ 30^s$ p.m., at 5280 feet. Deep blue, dotted with small cumuli; sun shining brightly.

At $6^h\ 2^m$ p.m., at 6547 feet. Deep blue, dotted with cirrocumuli.

August 18.

At $1^h\ 9^m$ p.m., at 3705 feet. Deep blue.

At $2^h\ 25^m\ 20^s$ p.m., at 14,434 feet. Very deep blue.

At $3^h\ 33^m$ p.m., at 15,984 feet. Very deep blue, dotted with cirrus clouds.

August 20.

At $7^h\ 49^m$ p.m., at 5900 feet. Blue.

September 1.

At $4^h\ 45^m$ p.m., at 270 feet. Blue sky near the horizon.

September 5.

At $1^h\ 21^m$ p.m., at 9926 feet. Deep blue.

September 8.

At $4^h\ 58^m\ 20^s$ p.m., at 4750 feet. Blue sky above.

At $5^h\ 11^m\ 25^s$ p.m., at 4440 feet. Blue.

At $5^h\ 12^m\ 30^s$ p.m., at 4920 feet. Deep blue.

DIRECTION OF THE WIND.

July 17.

The direction of the wind before starting was S.W.

At $10^h\ 27^m$ a.m., at 19,374 feet, we determined, by means of the compass and the inclination of the grapnel hanging below, that we were moving in the direction of N.E., and therefore the wind was from the S.W.

At $10^h\ 44^m$ a.m., at 19,336 feet, we seemed to be moving towards the north; if so, the wind was S.

July 30.

The direction of the wind before starting was N.W.

At $4^h\ 41^m\ 15^s$ p.m., at 480 feet, the direction of the wind was S.W.

At $5^h\ 17^m\ 30^s$ p.m., at 5155 feet, the direction of the wind was N.N.W.

At $5^h\ 40^m\ 30^s$ p.m., at 6183 feet, the direction of the wind was N.

August 18.

The direction of the wind before starting was N.W.

At $1^h\ 5^m$ p.m., at 1130 feet, the direction of the wind was N.N.E.

At $1^h\ 17^m$ p.m., at 8935 feet, the direction of the wind was N.W.

August 20.

The direction of the wind before starting was S.W., with very gentle motion. No observations of the direction of the wind were made during this ascent, as the air was almost calm.

August 21.

The direction of the wind before starting was S.W. No observations of the direction of the wind were made during this ascent.

September 1.

The direction of the wind before starting was E.N.E., verging to E.
At 5^h 4^m p.m., at 3268 feet, the direction of the wind was E.N.E.
At 5^h 10^m p.m., at 3318 feet, the direction of the wind was E.
At 5^h 11^m 30^s p.m., at 3560 feet, the direction of the wind was E.S.E.
At 5^h 17^m p.m., at 3580 feet, the direction of the wind was E.N.E.
At 5^h 36^m p.m., at 4190 feet, upper current W.

September 5.

The direction of the wind before starting was N.
At 2^h 16^m 10^s p.m., at 11,150 feet, the direction of the wind was E.

September 8.

The direction of the wind before starting was S.W. No observations of the direction of the wind could be taken during this ascent.

ON THE PROPAGATION OF SOUND.

On July 17, when at the height of 11,800 feet above the earth a band was heard playing.

On July 30, at 5450 feet a gun was heard with a sharp sound, then a drum beating, and then a band was heard.

On August 18, at 4500 feet the shouting of people was heard.
,, at 18,000 feet a clap of thunder was heard.
,, at 20,000 feet thunder again heard, below us.
,, at 20,000 feet a loud clap of thunder was heard.

On August 20, at 4000 feet heard the shouts of people.
,, at 4300 feet railway whistle heard.
,, at 3500 feet heard bell tolling.
,, at 2200 feet heard people shouting.
,, at 3700 feet heard a clock strike.

On August 21, at 4900 feet a railway-train was heard.
,, at 8200 feet a gun was heard.
,, at 3500 feet heard people shouting.

On September 5, at 6730 feet, ascending, the report of a gun was heard.
,, at 10,070 feet, descending, the report of a gun was heard.

On September 8, at 3300 feet heard the shouts of people.

From these results we learn that different notes and sounds pass more readily through the air than others. A dog barking has been heard at the height of two miles; a multitude of people shouting, not more than 4500 feet.

On August 18 we heard at three different times what, in my Notes to the Observations, I have called claps of thunder; but I also remarked at these times that a careful examination of the clouds below us failed to discover any thunder-cloud. On inquiry afterwards as to the fact of thunder being heard on the earth, we found none had been, and it was suggested that the sounds we heard might have proceeded from Birmingham, where guns were being proved on that day. It is possible this suggestion may be correct.

Physiological Observations.

On July 17, before starting from Wolverhampton, at my request Mr. Coxwell took the number of his pulsations, and found 74 in one minute; my pulsations were 76 in one minute. At the height of 17,000 feet mine had increased to 100, and Mr. Coxwell's to 84. On regaining the ground the number of both our pulsations was 76.

On August 18, the number of our pulsations were both 76 before starting. At the height of 22,000 feet mine had increased to 100, and Mr. Coxwell's to 98; and afterwards, at a higher elevation, Mr. Coxwell's number was 110, and mine 107.

On August 21, in the morning ascent no observations were taken of our pulsations before leaving. At the height of 1000 feet the following results were obtained:—Mr. Coxwell's, 95 in a minute; Mr. Ingelow's, 80 in a minute; Capt. Percival's, 90 in a minute. At 11,000 feet:—Mr. Coxwell's, 90 in a minute; Mr. Ingelow's, 100 in a minute; Capt. Percival's, 88 in a minute; mine, 88 in a minute; my son's (a boy in his 14th year), 89 in a minute. At 14,000 feet the following were the results:—Mr. Coxwell's, 94 in a minute; mine, 98 in a minute; Mr. Ingelow's, 112 in a minute; Capt. Percival's, 78 in a minute; my son's, 89 in a minute. The pulsations of Capt. Percival were so weak that he could scarcely count them, whilst those of Mr. Coxwell, he considered, had increased in strength.

These results show that the effect of diminished pressure exercises a very different influence upon different individuals, depending probably upon temperament and organization.

In the ascent on July 17, at the height of 19,000 feet the hands and lips were noted as dark bluish, but not the face. At the height of four miles the palpitations of the heart were audible and the breathing was affected, and at higher elevations considerable difficulty was experienced in respiration.

On August 18, the hands and face were blue at the height of 23,000 feet.

On September 5, at the height of about 29,000 feet I became unconscious, and at the height of about 35,000 feet Mr. Coxwell lost the use of his hands. At the height of about 29,000 feet I began to recover, and resumed observing at the height of 25,000 feet.

From these results it would seem that the effect of high elevations is different upon the same individual at different times.

On the Different Appearance of the Gas in the Balloon.

July 17.

Before starting the gas was thick and opaque.

At 9^h 54^m a.m., at 8065 feet. Valve opened, gas opaque.

At 10^h 2^m a.m., at 11,792 feet. Balloon full, gas opaque.

At 10^h 15^m a.m., at 16,914 feet. Gas cleared in balloon from appearance of smoke to transparency.

July 30.

Before starting the gas was thick and opaque.

At 4^h 40^m 30^s p.m., at 330 feet. Gas clear and transparent.

At 4^{h} 45^{m} 30^{s} p.m., at 2379 feet. Gas getting thick again.

At 5^{h} 31^{m} p.m., at 5380 feet. Gas partially clear.

August 18.

Before starting the gas was cloudy and opaque.

At 1^{h} 18^{m} 55^{s} p.m., at 9978 feet. Balloon full, gas cloudy.

At 1^{h} 21^{m} p.m., at 11,470 feet. Valve opened.

At 1^{h} 25^{m} p.m., at 9740 feet. Valve opened.

At 1^{h} 32^{m} p.m., at 7650 feet. Valve opened.

At 2^{h} 22^{m} p.m., at 12,364 feet. Balloon full, gas clear.

At 2^{h} 25^{m} 20^{s} p.m., at 14,434 feet. Gas getting opaque.

August 20.

Before starting the gas was thick and opaque.

At 6^{h} 39^{m} p.m., at 3359 feet. Gas still opaque.

At 6^{h} 41^{m} 30^{s} p.m., at 3986 feet. Gas very opaque, issuing from the neck as smoke.

At 7^{h} 4^{m} p.m., at 4052 feet. Gas opaque, issuing from the neck as smoke.

At 7^{h} 18^{m} p.m., at 1417 feet. Gas clear; can see netting plainly through the balloon.

At 7^{h} 22^{m} p.m., at 1587 feet. Gas issuing from the neck of the balloon; still clear.

At 7^{h} 25^{m} p.m., at 2067 feet. Gas clear.

At 7^{h} 37^{m} p.m., at 2603 feet. Gas opaque.

At 7^{h} 52^{m} p.m., at 5200 feet. Gas opaque.

August 21.

Before starting the gas was thick and opaque.

At 5^{h} 35^{m} a.m., at 14,027 feet. Gas clear; netting plainly visible through the balloon.

September 1.

Before starting the gas was thick and opaque.

At 4^{h} 55^{m} p.m., at 2214 feet. Gas still opaque.

At 5^{h} 1^{m} 30^{s} p.m., at 3170 feet. Gas very opaque.

At 5^{h} 15^{m} p.m., at 3680 feet. Gas very opaque, issuing from the neck very fast, like smoke.

At 5^{h} 26^{m} p.m., at 3837 feet. Gas very opaque.

At 5^{h} 30^{m} p.m., at 4000 feet. Gas opaque, issuing from the neck like smoke.

September 5.

Before starting the gas was very opaque. During this ascent no observations of the state of the gas were made.

September 8.

Before starting the gas was opaque.

At 4^{h} 49^{m} p.m., at 1232 feet. Gas was clear.

At 4^{h} 51^{m} p.m., at 2432 feet. Gas getting opaque; netting scarcely visible through the balloon.

At 4^{h} 52^{m} 30^{s} p.m., at 2923 feet. Gas opaque.

At 5^{h} 15^{m} 35^{s} p.m., at 5026 feet. Gas partially clear.

At 5^{h} 23^{m} 50^{s} p.m., at 5029 feet. Gas opaque, issuing from the neck of the balloon.

At 5^{h} 28^{m} p.m., at 4829 feet. Gas very clear.

At 5^{h} 52^{m} 14^{s} p.m., at 600 feet. Gas clear.

General Remarks.

These eight ascents have led me to conclude, firstly, that it was necessary to employ a balloon containing nearly 90,000 cubic feet of gas; and that it was impossible to get so high as six miles, even with a balloon of this magnitude, unless carburetted hydrogen, varying in specific gravity from 370 to 330, had been supplied for the purpose.

It is true that these statements are rather conflicting when compared with the statements made by one or two early travellers, who professed to have reached some miles in height with small balloons. But if we recollect that at 3¾ miles high a volume of gas will double its bulk, we have at once a ready means of determining how high a balloon can go; and in order to reach an elevation of six or seven miles it is obvious that one-third of the capacity of the balloon should be able to support the entire weight of the balloon, inclusive of sufficient ballast for the descent.

The amount of ballast taken up affords another clue as to the power of reaching great heights. Gay-Lussac's ballast, as before mentioned, was reduced to 33 lbs. Rush and Green, when their barometers, as stated by them, stood at 11 inches, had only 70 lbs. left, and this was considered a sufficient playing-power. We found that it was desirable to reserve five or six hundred pounds; and although we could have gone higher by saving less, still on every occasion it was evident that a large amount of ballast was indispensable to regulate the descent and select a favourable spot for landing.

Secondly, it was manifest throughout our various journeys that excessive altitude and extended range as to distance are quite incompatible. The reading of the instruments establishes this; and it has been pointed out what a short time the balloon held its highest place, and how reluctantly it appeared to linger even at a somewhat less elevation. This was not owing to any leakage or imperfection in the balloon itself, for its efficiency has been well tested, and it remained intact a whole night without the least perceptible loss of gas.

It has been stated by an aëronaut of experience that strong opposing upper currents have been heard to produce an audible contention, and to sound like the *"roaring of a hurricane."* Now, the only deviation we experienced from the most perfect stillness was a slight whirring noise in the netting, and this only when the balloon was rising with great rapidity, and a slight flapping on descending, when the balloon is in a collapsed state.

I may also state that the too readily accepted theory as to the prevalence of a settled west or north-west wind was not confirmed in our trips. Nor was the appearance of the upper surface of the clouds such as to establish the theory that the clouds assume a counterpart of the earth's surface below, and rise or fall like hills or dales.

The formation of vapour along the course and sinuosities of the river during an ascent from the Crystal Palace has been already alluded to; this was a very remarkable demonstration.

General Conclusions.

Perhaps the most important conclusions which can be drawn from the experiments at present are:—

1. That the temperature of the air does not decrease uniformly with increase of elevation above the earth's surface, and consequently the theory of a decline of temperature of 1° in every 300 feet must

be abandoned. In some cases, with a clear sky, the decline of 1° has taken place within 100 feet of the earth, and for a like decrease of temperature it is necessary to pass through more than 1000 feet at heights exceeding 5 miles.

The determination of the decrease of temperature with elevation, and its law, is most important, and the balloon is the only means by which this element can be determined; very many more experiments are, however, necessary.

2. That the humidity of the air decreases with height in a wonderfully decreasing ratio, till at heights exceeding five miles the amount of aqueous vapour in the atmosphere is very small indeed.
3. That an aneroid barometer read correctly to the first place, and probably to the second place of decimals, to a pressure as low as 7 inches.
4. That dry- and wet-bulb thermometers can be used effectively up to any heights on the earth's surface where man can be located.
5. That the balloon affords a means of solving with advantage many delicate questions in physics; and,
6. That the observations can be made with tolerable safety to the observer; and therefore that the balloon may be used as a philosophical agent in many investigations.

List of Stations where Meteorological Observations were made on the days of the several Balloon Ascents.

Names of Stations.	Latitude.	Longitude.	Height above Sea-level.	Observer.
	° ′	° ′	feet.	
Greenwich	51 28 N.	0 0	158	The Astronomer Royal.
Wrottesley	52 37	2 13	531	Lord Wrottesley.
Wolverhampton	52 37	2 13	490	
Belvoir Castle	52 54	0 39 W.	260	W. Ingram, Esq.
Grantham	52 54	0 39	181	J. W. Jeans, Esq.
Nottingham	52 57	......	174	E. J. Lowe.
Hawarden	53 11	3 2	260	Dr. Moffat.
Liverpool	53 25	3 0	37	J. Hartnup, Esq.
Wakefield	53 40	1 30	115	W. R. Milner, Esq.

Meteorological Observations made at different Stations in connexion with the Balloon Ascent on

July 17.

ROYAL OBSERVATORY, GREENWICH.

Time of Observation.	Reading of			Temp. of the Dew-point.	Tension of Vapour.	Degree of Humidity.	Direction of Wind.	Amount of Cloud 0-10.	Amount of Ozone.	Remarks.
	Barom. reduced to 32° F.	Thermom. Dry.	Thermom. Wet.							
h m	in.	°	°	°	in.					
9 0 a.m.	29·73	62·0	57·2	53·1	·404	73	W.	5	5	Cirrocumulus, cirrostratus, and cirrus.
9 10 „	29·73	62·0	57·0	52·7	·399	72	...	5	...	
9 20 „	29·73	62·0	57·0	52·7	·399	72	...	6	...	
9 30 „	29·73	62·0	56·4	51·6	·382	69	W.	6	...	Cirrocumulus, cirrostratus.
9 40 „	29·73	63·7	57·8	52·9	·401	68	...	6	...	
9 50 „	29·73	63·3	57·5	52·6	·397	68	...	6	...	Cirrus, cirrocumulus, cumulus, stratus.
0 „	29·74	63·9	57·8	52·8	·400	67	W.	7	...	Light cloud, fine and bright.
10 „	29·74	63·9	57·5	52·2	·391	66	...	7	...	
20 „	29·74	63·4	56·8	50·0	·361	65	...	8	...	
30 „	29·74	64·2	58·0	54·6	·427	71	S.W.	7	...	
40 „	29·74	64·6	58·2	54·7	·428	71	...	6	...	
50 „	29·73	63·9	57·3	51·9	·386	65	...	5	...	
1 0 „	29·73	64·6	57·5	51·6	·382	63	S.W.	5	...	Cirrus, cirrocumulus, cumulo-stratus, and cirrostratus.
1 10 „	29·73	63·1	56·8	51·5	·381	66	...	6	...	
1 20 „	29·73	65·3	58·0	52·1	·389	62	...	7	...	
1 30 „	29·73	67·7	59·9	53·7	·413	61	S.W.	8	...	
1 40 „	29·73	63·7	56·8	51·1	·375	63	...	10	...	Overcast entirely.
1 50 a.m.	29·73	63·4	58·0	53·5	·410	71	...	10	...	Cirrus, cirrostratus, and cumulostratus.
Noon.	29·73	66·5	59·5	53·9	·416	64	S.W.	9	0	Cirrus, cirrocumulus, cirrostratus, and cumulostratus.
10 p.m.	29·73	64·6	57·7	52·0	·388	63	...	7	...	
20 „	29·72	66·1	59·7	54·4	·424	66	...	5	...	
30 „	29·72	66·7	59·5	53·7	·413	64	S.W.	5	...	
40 „	29·72	68·8	61·2	55·3	·437	62	...	9	...	
50 „	29·72	65·5	58·5	52·8	·400	64	...	7	...	
1 0 „	29·72	64·7	58·3	53·0	·403	68	S.W.	7	...	
1 10 „	29·72	65·9	59·0	53·7	·413	64	...	6	...	Light clouds; a splendid day.
1 20 „	29·72	68·2	60·5	54·5	·425	61	...	7	...	
30 „	29·72	66·4	59·5	53·9	·416	65	S.W.	8	...	
40 „	29·72	66·2	59·5	54·1	·419	65	...	7	...	
50 „	29·72	66·7	59·8	54·3	·422	64	...	5	...	
0 „	29·72	63·4	57·2	52·0	·388	67	S.W.	7	...	
10 „	29·73	63·2	57·3	52·3	·393	67	...	8	...	Cirrus, cirrocumulus, and cirrostratus.
20 „	29·73	63·4	57·3	52·2	·391	67	...	9	...	
30 „	29·73	63·7	58·0	53·3	·407	69	S.W.	9	...	
40 „	29·73	63·0	57·8	53·4	·409	71	...	10	...	Dull-looking, clouds in S.W.
50 „	29·73	62·3	57·2	52·8	·400	72	...	10	...	Generally overcast; rain has just commenced falling.
0 „	29·72	62·4	57·8	53·9	·416	74	S.W.	10	0	Generally overcast; rain ceased.
10 „	29·72	63·1	57·9	53·5	·410	71	...	10	...	
20 „	29·72	62·8	57·6	53·2	·406	71	...	10	...	
30 „	29·72	62·4	57·2	52·7	·399	71	S.W.	10	...	
40 „	29·73	61·7	56·4	51·8	·385	72	...	10	...	
50 „	29·73	61·7	56·7	52·4	·394	72	...	10	...	
0 „	29·73	63·2	57·2	52·1	·389	67	S.W.	10	...	
10 „	29·73	60·5	56·0	52·1	·389	74	...	10	...	
20 „	29·73	60·4	57·0	54·1	·419	80	...	10	...	
30 „	29·73	60·1	55·1	50·7	·370	71	S.W.	10	...	
40 „	29·72	60·0	54·9	50·4	·366	71	...	10	...	
50 „	29·73	60·0	55·2	51·0	·374	72	...	10	...	
0 p.m.	29·72	60·1	55·3	49·1	·349	72	S.W.	10	...	

Meteorological Observations made at different Stations in connexion with the Balloon Ascent on

July 17 (*continued*).

WROTTESLEY HALL.

Time of Observation.	Reading of			Temp. of the Dew-point.	Tension of Vapour.	Degree of Humidity.	Direction of Wind.	Amount of Cloud 0–10.	Amount of Ozone.	Remarks.
	Barom. reduced to 32° F.	Thermom.								
		Dry.	Wet.							
h m	in.	°	°	°	in.					
9 40 a.m.	29·33	58·0	52·8	48·1	·336	70	s.w.			
9 50 „	29·33	59·2	53·9	49·2	·351	70	s.s.w.	...	...	Fine.
10 0 „	29·33	60·4	55·0	50·3	·365	69	s.s.w.			
10 10 „	29·33	59·7	53·0	47·2	·325	63	s.s.w.			
10 20 „	29·33	59·0	53·1	47·9	·334	67	s.s.w.	...	...	Fine.
10 30 „	29·32	59·8	54·3	49·5	·355	71	s.s.w.			
10 40 „	29·32	59·0	53·9	49·3	·352	70	s.s.w.			
10 50 „	29·32	60·4	55·0	50·3	·365	69	s.s.w.	...	...	Fine.
11 0 „	29·32	59·0	53·2	48·1	·336	67	s.w.			
11 10 „	29·32	58·4	53·9	49·9	·360	71	s.s.w.			
11 20 „	29·32	62·7	56·9	52·0	·388	69	s.s.w.	...	...	Fine.
11 30 „	29·32	59·0	53·2	48·1	·336	67	s.s.w.			
11 40 „	29·32	62·0	56·0	50·8	·371	67	s.s.w.			
11 50 a.m.	29·32	60·0	50·0	41·2	·259	50	s.s.w.	...	...	Fine.
Noon.	29·31	62·2	55·8	50·3	·365	65	s.s.w.			
0 10 p.m.	29·31	60·1	53·9	48·4	·340	65	s.s.w.			
0 20 „	29·31	61·0	54·9	49·6	·356	66	s.w.	...	...	Dull.
0 30 p.m.	29·31	62·2	55·8	50·3	·365	65	s.	...	...	Dull.

WOLVERHAMPTON.

9 20 a.m.	29·44	59·0	55·0	51·4	·379	76	s.w.	7	...	Great masses of cumulostratus clouds.
9 52 „	29·42	59·0	54·8	51·0	·370	75	s.w.	8		
9 55 „	29·44	59·0	54·8	51·0	·370	75	s.w.	7	...	Balloon stationary.
10 0 „	......	59·5	54·8	50·8	·371	72	s.w.	9	...	Balloon invisible; passed behind the clouds.
10 10 „	......	60·0	55·0	50·6	·369	71	s.w.	8	...	Great masses of cumulostratus.
10 15 „	......	59·0	55·0	51·4	·379	76	s.w.	8	...	
10 20 „	29·41	59·3	55·3	51·7	·384	76	s.w.	8	...	
10 30 „	29·41	61·0	55·8	51·3	·378	71	s.w.	7	...	
10 40 „	29·40	61·3	57·0	53·3	·407	76	s.w.	8	...	
10 55 „	......	61·5	57·0	53·1	·404	75	s.w.	6	...	
11 0 „	29·41	61·4	56·8	52·8	·400	74	s.w.	7	...	
11 10 „	......	62·2	56·9	52·3	·393	71	s.w.	6	...	
11 15 „	29·41	62·5	57·0	52·3	·393	69	s.w.	6	...	
11 25 a.m.	29·42									

BELVOIR CASTLE.

9 0 a.m.	29·54	69·5	56·3	51·8	·385	71	s.w.	...	4	Fine.
3 0 p.m.	29·53	64·0	56·5	50·3	·365	61	s.w.	...	3	Fair, but cloudy.

NOTTINGHAM.

9 0 a.m.	29·70	58·6	54·3	50·4	·366	75	w.	6·5	2	Fine.
3 0 p.m.	29·66	66·9	61·2	56·6	·459	70	w.	7	...	Fine.
10 0 p.m.	29·61	52·0	49·7	47·5	·329	85	s.w.	7	...	Fine.

Meteorological Observations made at different Stations in connexion with the Balloon Ascent on

July 17 (*continued*).

HAWARDEN.

Time of Observation.	Reading of			Temp. of the Dew-point.	Tension of Vapour.	Degree of Humidity.	Direction of Wind.	Amount of Cloud 0–10.	Amount of Ozone.	Remarks.
	Barom. reduced to 32° F.	Thermom.								
		Dry.	Wet.							
h m	in.	°	°	°	in.					
10 0 a.m.	29·51	58·5	54·0	50·0	·361	73	W.S.W.	3		
4 0 p.m.	29·47	56·5	54·0	51·7	·384	84	S.	...	4	

LIVERPOOL.

7 45 a.m.	29·81	59·8	54·8	50·4	·366	71	...	...	...	About three-fourths of the sky were covered with cloud till noon; overcast afterwards. Rain fell from 3 to 8½ p.m.
9 0 a.m.	29·81	61·2	55·0	49·7	·357	66	...	...	...	
1 0 p.m.	29·80	64·8	62·1	59·8	·514	88	...	...	...	
3 0 p.m	29·80	59·5	65·6	52·1	·389	77	...	...	...	
9 0 p.m.	29·69	56·0	53·7	51·5	·381	87	...	...	...	

WAKEFIELD.

3 0 a.m.	29·57	56·5	54·0	51·7	·384	84	S.			
9 0 a.m.	29·67	63·0	56·5	51·0	·374	65	S.W.			
3 0 p.m.	29·66	64·5	57·5	51·7	·384	63	S.W.			
9 0 p.m.	29·62	56·0	54·0	52·1	·389	87	E.			

July 30.

ROYAL OBSERVATORY, GREENWICH.

4 0 p.m.	29·93	67·6	59·0	52·2	·391	58	N.E.	9	...	Cirrocumulus, cumulostratus, and cirrostratus.
4 10 „	29·93	67·5	57·0	48·6	·343	50	...	10	...	Dense cirrostratus in E.; bright cirrocumulus and cumulostratus in S.W.
4 20 „	29·93	67·4	57·4	49·4	·353	53	...	10	...	
4 30 „	29·93	67·1	57·7	50·1	·362	54	N.	10	...	A little clear sky in N.; elsewhere cirrocumulus and cumulostratus.
4 40 „	29·93	66·9	57·5	50·0	·361	56	...	10	...	Cirrocumulus, cumulostratus, cirrostratus, and a little cirrus.
4 50 „	29·93	66·5	57·4	50·1	·362	56	...	10	...	
5 0 „	29·93	66·9	57·0	49·1	·349	54	N.W.	10	...	
5 10 „	29·93	66·5	57·5	50·3	·365	56	...	...	...	
5 20 „	29·93	67·1	57·9	50·6	·369	55	...	10	...	[S. by E. Balloon last seen about $5^{h}\,25^{m}$
5 30 „	29·93	66·5	57·0	49·3	·352	55	N.W.	8	...	Clear sky, principally in W. and zenith; elsewhere cirrus, cirrocumulus, and cumulostratus.
5 40 „	29·93	66·5	58·0	51·1	·375	59	..	8	...	Clear in S.S.E.; principally cirrus, cirrocumulus, and cumulostratus.
5 50 „	29·93	67·2	57·3	49·4	·353	53	...	5	...	Clear sky in W.S.W. and N.; dense cumulostratus in E. and S.E., cirrus, and cirrocumulus.
6 0 „	29·93	66·9	57·7	50·3	·365	56	N.N.W.	5	0	Half the sky covered with cirrus, cirrocumulus, cirrostratus, and cumulostratus.
7 0 „	29·93	63·6	...	...	...	...	W.N.W.			
8 0 „	29·95	60·8	...	...	...	...	W.S.W.			
9 0 „	29·96	58·9	54·0	49·6	·356	72	W.S.W.	3	0	Light cirrus, cirrocumulus, and cirrostratus.

Meteorological Observations made at different Stations in connexion with the Balloon Ascent on

August 18.

ROYAL OBSERVATORY, GREENWICH.

Time of Observation.	Reading of Barom. reduced to 32° F.	Reading of Thermom. Dry.	Reading of Thermom. Wet.	Temp. of the Dew-point.	Tension of Vapour.	Degree of Humidity.	Direction of Wind.	Amount of Cloud 0–10.	Amount of Ozone.	Remarks.
h m	in.	°	°	°	in.					
Noon	29·79	59·7	56·5	53·7	·413	82	N.W.	10	1	Overcast; cirrostratus.
0 10 p.m.	29·80	60·0	57·0	54·4	·424	82	...	10	...	
0 20 ,,	29·80	59·7	56·7	54·1	·419	82	...	10	...	
0 30 ,,	29·80	60·3	56·8	54·0	·418	79	N.W.	10	...	
0 40 ,,	29·81	60·9	56·8	53·3	·407	76	...	10	...	
0 50 ,,	29·82	60·7	56·9	53·7	·413	77	...	10	...	
1 0 ,,	29·81	60·4	57·5	55·0	·433	82	N.N.W.	10	...	
1 10 ,,	29·81	61·0	57·8	55·0	·433	81	...	10	...	
1 20 ,,	29·81	60·6	57·3	54·4	·424	81	...	10	...	
1 30 ,,	29·81	60·5	57·2	54·4	·424	81	N.W.	10	...	
1 40 ,,	29·81	60·5	57·5	54·9	·431	83	...	10	...	
1 50 ,,	29·81	60·1	56·9	54·1	·419	81	...	10	...	
2 0 ,,	29·81	60·4	57·1	54·3	·422	81	N.N.W.	10	...	
2 10 ,,	29·81	60·5	57·2	54·4	·424	81	...	10	...	
2 20 ,,	29·81	60·4	57·2	54·3	·422	81	...	10	...	
2 30 ,,	29·81	60·3	57·2	54·5	·425	82	N.W.	10	...	
2 40 ,,	29·81	60·3	57·3	54·7	·428	82	...	10	...	
2 50 ,,	29·81	60·5	57·3	54·5	·425	82	...	10	...	The clouds have just commenced to break.
3 0 ,,	29·80	61·5	58·3	55·6	·443	82	N.	10	1	Overcast.
3 10 ,,	29·81	60·2	57·5	55·1	·434	84	...	10	...	
3 20 ,,	29·81	60·1	57·4	55·0	·433	84	...	10	...	
3 30 ,,	29·80	59·9	57·3	55·1	·434	85	N.	10	...	
3 40 ,,	29·79	60·3	57·8	55·6	·443	85	...	10	...	
3 50 ,,	29·79	59·7	57·4	55·4	·439	86	...	10	...	
4 0 ,,	29·79	59·7	57·3	55·2	·436	86	N.	10	...	

WROTTESLEY HALL.

1 0 p.m.	29·47	61·7	57·1	53·1	·404	75	N.W.	...	...	Fine.
1 10 ,,	29·47	63·1	58·5	54·6	·427	74	W.N.W.			
1 20 ,,	29·47	63·0	57·9	53·6	·412	71	N.W.			
1 30 ,,	29·47	62·1	56·9	52·4	·394	71	N.W.			
1 40 ,,	29·47	62·9	57·1	52·2	·391	68	N.W.	...	...	Fine.
1 50 ,,	29·47	64·0	58·5	53·9	·416	69	W.N.W.			
2 0 ,,	29·47	63·6	57·6	52·6	·397	67	N.by W.			
2 10 ,,	29·46	64·5	58·8	52·0	·388	69	N.N.W.	...	...	Fine.
2 20 ,,	29·46	64·4	58·4	53·4	·409	67	W.N.W.			
2 30 ,,	29·46	64·6	58·5	53·4	·409	67	W.N.W.			
2 40 ,,	29·46	65·4	59·0	53·8	·415	67	N.W.	...	...	Fine.
2 50 ,,	29·45	65·9	59·8	54·8	·430	68	W.			
3 0 ,,	29·45	66·0	59·7	54·6	·427	67	W.N.W.			
3 10 ,,	29·45	66·2	59·2	53·5	·410	64	W.	...	...	Fine.
3 20 ,,	29·45	66·6	59·9	54·5	·425	65	W.			
3 30 ,,	29·44	66·8	59·9	54·1	·419	64	W.			
3 40 ,,	29·44	66·0	59·0	53·3	·407	64	W.			
3 50 ,,	29·44	66·9	60·0	54·5	·425	65	W.	...	...	Fine.
4 0 ,,	29·44	67·0	59·9	54·2	·421	63	W.S.W.			
4 10 ,,	29·44	67·2	59·4	53·3	·407	61	S.S.W.	...	...	Fine.

Meteorological Observations made at different Stations in connexion with the Balloon Ascent on

August 18 (*continued*).

BELVOIR CASTLE.

Time of Observation.	Reading of			Temp. of the Dew-point.	Tension of Vapour.	Degree of Humidity.	Direction of Wind.	Amount of Cloud 0–10.	Amount of Ozone.	Remarks.
	Barom. reduced to 32° F.	Thermom.								
		Dry.	Wet.							
h m	in.	°	°	°	in.					
9 0 a.m.	29·63	56·7	53·3	50·2	·364	79	N.	...	8	Cloudy.
3 0 p.m.	29·63	68·0	59·0	51·9	·386	56	S.W.	...	0	Fair.

NOTTINGHAM.

9 0 a.m.	29·83	64·0	58·0	53·0	·403	67	N.N.E.	8	0	Dull till 8ʰ a.m.; the clouds then broke.
11 30 „	29·84	65·4	58·9	53·6	·412	66	N.N.E.	1	...	From this time very fine and warm.
3 0 p.m.	29·83	75·7	63·5	54·8	·430	49	N.N.W.	2	...	Very fine.
9 50 „	29·83	57·2	55·6	54·1	·419	89	W.N.W.	1	...	Very fine.

HAWARDEN.

10 0 a.m.	29·70	63·0	58·0	53·8	·415	72	N.W.	2	1	
4 0 p.m.	29·67	63·0	57·0	51·9	·386	67	N.W.	1	2	

LIVERPOOL.

7 45 a.m.	30·00	59·0	55·5	52·4	·394	79	...	...	...	About half the sky was covered with cumuli and cirri till 1ʰ p.m.; afterwards quite clear.
9 0 „	30·00	60·8	56·0	51·9	·386	72	...	...	...	
1 0 p.m.	30·00	63·7	58·0	53·3	·407	70	...	...	...	
3 0 „	30·00	64·4	57·8	52·3	·393	64	...	...	...	
9 0 „	29·99	59·4	56·5	53·9	·416	85	...	...	...	

WAKEFIELD.

3 0 a.m.	29·78	42·5	42·0	40·8	·255	92	E.N.E.			
9 0 „	29·85	68·0	61·0	55·5	·441	64	N.W.			
3 0 p.m.	29·80	71·5	63·0	58·3	·487	63	W.N.W.			
9 0 „	29·82	54·0	53·0	52·0	·388	93	W.			

August 20.

ROYAL OBSERVATORY, GREENWICH.

6 0 p.m.	29·82	64·3	62·3	60·6	·529	88	N.N.W.	10	0	The sky is generally covered with light cirrus, cirrostratus, and haze; a very calm evening.
6 10 „	29·82	64·2	62·1	60·3	·524	88	...	10	...	
6 20 „	29·82	64·1	61·6	59·5	·509	85	...	10	...	
6 30 „	29·82	63·7	62·0	60·6	·529	90	N.N.W.	9	...	Very hazy all round the horizon; cirrus clouds are prevalent; the Crystal Palace is scarcely discernible.
6 40 „	29·81	62·5	61·8	61·2	·541	96	...	9	...	
6 50 „	29·81	63·1	61·6	60·3	·524	91	...	9	...	Cirrus clouds prevail generally; the haze thickens; the sky is partially free from clouds in the zenith.
7 0 „	29·81	62·8	61·0	59·5	·509	89	N.N.E.	10	...	The sky appears uniformly covered with cirrus, cirrostratus, and haze.
7 10 „	29·81	62·6	60·0	57·9	·480	84	...	10	...	Cirrostratus and haze.
7 20 „	29·81	62·5	60·2	58·3	·487	86	...	10	...	
7 30 „	29·81	62·7	60·3	58·3	·487	86	N.E.	10	...	

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Meteorological Observations made at different Stations in connexion with the Balloon Ascent on

August 21.

ROYAL OBSERVATORY, GREENWICH.

Time of Observation.	Reading of			Temp. of the Dew-point.	Tension of Vapour.	Degree of Humidity.	Direction of Wind.	Amount of Cloud 0–10.	Amount of Ozone.	Remarks.
	Barom. reduced to 32° F.	Thermom.								
		Dry.	Wet.							
h m	in.	°	°	°	in.					
August 20. Midnight	29·82	59·7	59·7	59·7	·512	100	S.S.E.	10	0	Overcast; amount of cloud variable.
August 21.										
1 0 a.m.	29·82	59·6	...	...	...	...	S.E.	...	...	Generally cloudy during the night and early morning.
2 0 ,,	29·82	59·1	...	...	...	...	S.E.	...	...	
3 0 ,,	29·81	58·8	...	...	...	...	S.E.	...	...	
4 0 ,,	29·81	58·0	...	...	...	...	S.	...	...	
5 0 ,,	29·80	58·6	...	...	...	...	S.S.E.	...	...	
6 0 ,,	29·80	58·8	...	...	...	...	S.W.	...	...	
7 0 ,,	29·80	59·6	...	...	...	...	E.S.E.	...	...	
8 0 ,,	29·80	62·0	...	...	...	...	E.S.E.	...	...	
9 0 ,,	29·79	64·3	62·5	60·9	·535	89	E.S.E.	10	0	

September 1.

ROYAL OBSERVATORY, GREENWICH.

4 0 p.m.	29·79	61·8	56·4	51·7	·384	70	E.	10	...	Sky is generally covered with cirrostratus.
4 10 ,,	29·79	61·5	56·3	51·8	·385	71	...	10	...	Overcast.
4 20 ,,	29·79	60·9	55·9	51·6	·383	71	...	10	...	
4 30 ,,	29·79	60·6	56·2	52·4	·394	74	E.N.E.	10	...	
4 40 ,,	29·79	60·3	56·0	52·3	·393	75	...	9	...	Sky generally covered with cirrostratus; rain falling very gently.
4 50 ,,	29·78	60·1	55·8	53·6	·412	80	...	9	...	Rain still falling very gently; cumulus clouds in the N.; light cirrostratus in the S.
5 0 ,,	29·78	60·1	55·8	53·6	·412	80	E.N.E.	10	...	Rain ceased; generally overcast.
5 10 ,,	29·78	60·1	56·2	52·8	·400	76	...	10	...	Cirrostratus, cirrocumulus, cumulostratus, and a little cirrus.
5 20 ,,	29·78	60·1	56·3	53·0	·403	77	...	10	...	Ditto; clouds clearing away.
5 30 ,,	29·78	59·7	55·9	52·6	·397	78	E.N.E.	9	...	Cirrus, cirrostratus, cirrocumulus, and cumulostratus.
5 40 ,,	29·78	59·6	56·1	53·0	·403	80	...	9	...	
5 50 ,,	29·78	59·4	56·0	53·0	·403	80	...	10	...	
6 0 ,,	29·78	59·0	55·7	52·7	·399	80	E.N.E.	10	...	
6 10 ,,	29·78	58·7	55·7	53·0	·403	81	...	10	...	
6 20 ,,	29·78	58·4	55·5	52·9	·401	82	...	9	...	Cirrocumulus, cirrostratus, and cumulostratus; clouds cover the greater part of the sky.
6 30 ,,	29·78	57·6	55·1	53·6	·412	84	N.E.	8	...	Light cirrus and clear sky in the S.; cirrocumulus and cirrostratus in the N.
6 40 ,,	29·78	57·2	55·0	53·0	·403	86	...	8	...	Cirrus, cirrostratus, and cumulostratus in E.
6 50 ,,	29·78	57·0	54·8	52·8	·400	85	...	8	...	Cirrus, cirrostratus, and cumulostratus in W. and N.W.
7 0 ,,	29·78	56·3	54·7	53·2	·406	89	N.E.	8	...	Clear sky and light clouds in zenith; dense cirrostratus round the horizon.

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Meteorological Observations made at different Stations in connexion with the Balloon Ascent on

September 5.

ROYAL OBSERVATORY, GREENWICH.

Time of Observation.	Reading of			Temp. of the Dew-point.	Tension of Vapour.	Degree of Humidity.	Direction of Wind.	Amount of Cloud 0–10.	Amount of Ozone.	Remarks.
	Barom. reduced to 32° F.	Thermom. Dry.	Thermom. Wet.							
h m	in.	°	°	°	in.					
Noon.	29·68	63·1	56·9	51·7	·384	66	N.E.	7	0	Cirrus, cirrostratus, cirrocumulus.
0 10 p.m.	29·68	64·3	57·6	52·0	·388	64	...	7	...	
0 20 „	29·68	65·2	58·5	53·0	·403	64	...	7	...	
0 30 „	29·68	65·8	58·6	52·7	·399	63	N.E.	7	...	
0 40 „	29·68	67·0	59·7	53·9	·416	62	...	8	...	Cirrus, cirrostratus, cumulostratus, and cirrocumulus.
0 50 „	29·69	65·8	58·7	53·9	·416	63	...	9	...	
1 0 „	29·69	64·5	57·8	52·2	·391	64	E.N.E.	10	...	
1 10 „	29·69	63·9	57·8	52·8	·400	67	...	10	...	Ditto; blue sky in N.W.
1 20 „	29·69	63·5	58·0	53·4	·409	70	...	9	...	Cirrus, cirrostratus, cirrocumulus and cumulostratus.
1 30 „	29·69	64·7	58·0	52·5	·396	65	S.W.	9	...	
1 40 „	29·70	65·9	58·4	52·3	·393	63	...	10	...	Cirrus and dense cirrostratus; rain has just commenced falling.
1 50 „	29·70	57·1	55·2	53·5	·410	87	...	10	...	Dense cirrostratus; rain falling heavily; strong negative electricity.
2 0 „	29·70	56·4	55·8	55·3	·437	96	S.E.	10	...	Overcast; cirrostratus; rain still falling.
2 10 „	29·70	56·3	55·7	55·2	·436	96	...	10	...	
2 20 „	29·70	56·6	55·9	55·4	·439	96	...	10	...	
2 30 „	29·70	57·2	56·5	55·8	·446	95	S.S.W.	10	...	
2 40 „	29·70	57·9	57·9	57·9	·480	100	...	10	...	Rain has ceased.
2 50 „	29·70	57·9	57·9	57·9	·480	100	...	10	...	Overcast; cirrostratus.
3 0 „	29·70	57·7	56·9	56·2	·453	95	S.S.W.	10	0	
3 10 „	29·70	58·0	56·8	55·7	·444	91	...	10	...	
3 20 „	29·70	57·7	56·6	56·6	·459	93	...	10	...	
3 30 „	29·70	57·9	56·8	56·8	·462	93	S.S.W.	10	...	
3 40 „	29·70	58·3	56·8	55·5	·441	90	...	10	...	
3 50 „	29·70	58·4	56·8	55·4	·439	89	...	10	...	
4 0 „	29·70	58·7	57·0	56·7	·461	89	S.S.W.	10	...	
4 10 „	29·70	58·4	56·8	55·3	·437	90	...	10	...	Overcast; cirrostratus and stratus.
4 20 „	29·70	58·5	56·9	55·4	·439	89	...	10	...	
4 30 „	29·70	58·2	57·0	55·9	·447	91	S.S.W.	10	...	Overcast; cirrostratus in N.; stratus.
4 40 „	29·70	57·8	56·0	54·4	·424	89	...	10	...	Overcast; stratus and cirrostratus.
4 50 „	29·71	57·4	56 6	55·9	·447	94	...	10	...	Overcast; rain.
5 0 „	29·71	57·2	56·4	55·7	·444	95	S.W.	10	...	
5 10 „	29·71	57·1	56·2	55·4	·439	94	...	10	...	
5 20 „	29·71	56·7	56·7	56·7	·461	100	...	10	...	Overcast; thin rain.
5 30 „	29·71	56·5	55·9	55·4	·439	96	N.W.	10	...	Overcast; rain ceased.
5 40 „	29·71	56·5	55·8	55·2	·436	96	...	9	...	Clouds broken.
5 50 „	29·71	56·4	56·4	56·4	·456	100	...	9	...	
6 0 „	29·71	56·4	56·4	56·4	·456	100	N.W.	9	...	Cirrostratus; blue sky in zenith; fine.

Meteorological Observations made at different Stations in connexion with the Balloon Ascent on

September 5 (*continued*).

Wrottesley Hall.

Time of Observation.	Reading of Barom. reduced to 32° F.	Reading of Thermom. Dry.	Reading of Thermom. Wet.	Temp. of the Dew-point.	Tension of Vapour.	Degree of Humidity.	Direction of Wind.	Amount of Cloud 0–10.	Amount of Ozone.	Remarks.
h m	in.	°	°	°	in.					
1 0 p.m.	29·37	57·6	52·9	48·6	·343	72	N.	...	...	Dull.
1 10 ,,	29·37	56·9	52·6	48·6	·343	76	N.			
1 20 ,,	29·37	57·0	52·7	48·7	·344	73	N.			
1 30 ,,	29·38	56·1	52·1	48·3	·339	75	N.	...	...	Dull.
1 40 ,,	29·38	55·5	51·8	48·3	·339	77	N.			
1 50 ,,	29·38	55·7	52·4	49·3	·352	80	N.			
2 0 ,,	29·38	55·8	52·7	49·1	·349	81	N.	...	...	Dull.
2 10 ,,	29·38	56·1	52·6	49·3	·352	77	N.			
2 20 ,,	29·38	56·8	53·2	49·9	·360	84	N.N.E			
2 30 ,,	29·39	57·0	53·2	49·7	·357	76	N.N.E.	...	...	Dull.
2 40 ,,	29·39	57·1	53·1	49·3	·352	75	N.N.E.			
2 50 ,,	29·39	57·1	53·4	50·0	·361	77	N.N.E.			
3 0 ,,	29·39	57·0	53·1	49·3	·352	75	N.N.E.	...	...	Dull.
3 10 ,,	29·39	57·2	53·4	49·9	·360	76	N.N.E.			
3 20 ,,	29·39	57·9	53·8	50·1	·362	75	N.N.E.			
3 30 ,,	29·39	58·1	54·0	50·3	·365	76	N.N.E.	...	...	Fine.
3 40 ,,	29·39	58·0	53·3	49·1	·349	72	N.E.			
3 50 ,,	29·39	58·0	53·9	50·2	·364	75	N.			
4 0 ,,	29·39	58·3	53·8	49·8	·358	74	N.	...	...	Fine.
4 10 ,,	29·39	58·2	53·9	49·1	·349	75	N.N.E.			
4 20 ,,	29·39	58·0	54·0	50·4	·366	76	N.N.W.			
4 30 ,,	29·39	58·0	54·2	50·7	·370	77	N.N.W.	...	...	Dull.
4 40 ,,	29·39	57·8	54·0	50·6	·369	77	N.N.W.			
4 50 ,,	29·40	57·6	53·8	50·3	·365	77	N.N.W.			

Hawarden.

Time of Observation.	Reading of Barom. reduced to 32° F.	Reading of Thermom. Dry.	Reading of Thermom. Wet.	Temp. of the Dew-point.	Tension of Vapour.	Degree of Humidity.	Direction of Wind.	Amount of Cloud 0–10.	Amount of Ozone.	Remarks.
10 0 a.m.	29·58	58·0	55·0	52·3	·393	81	E.	4	0	
4 0 p.m.	29·62	59·0	55·5	53·3	·407	84	N.E.	4	0	

Liverpool.

Time of Observation.	Reading of Barom. reduced to 32° F.	Reading of Thermom. Dry.	Reading of Thermom. Wet.	Temp. of the Dew-point.	Tension of Vapour.	Degree of Humidity.	Direction of Wind.	Amount of Cloud 0–10.	Amount of Ozone.	Remarks.
7 45 a.m.	29·96	53·1	51·2	49·3	·352	87	...	...	...	The sky was nearly free fr cloud in the early morn From 9^h to 1^h overca afternoon fine.
9 0 ,,	29·89	56·0	52·7	49·6	·356	79	...	...	...	
1 0 p.m.	29·93	60·8	53·9	47·9	·334	72	...	...	...	
3 0 ,,	29·93	60·3	55·8	52·5	·396	76	...	...	...	
9 0 ,,	29·98	56·7	54·1	51·7	·384	90	...	...	...	

September 8.

Royal Observatory, Greenwich.

Time of Observation.	Reading of Barom. reduced to 32° F.	Reading of Thermom. Dry.	Reading of Thermom. Wet.	Temp. of the Dew-point.	Tension of Vapour.	Degree of Humidity.	Direction of Wind.	Amount of Cloud 0–10.	Amount of Ozone.	Remarks.
4 0 p.m.	29·92	67·0	63·2	60·2	·522	79	S.W.	10	...	Generally overcast.
4 10 ,,	29·92	66·8	63·2	60·3	·524	80	...	10	...	
4 20 ,,	29·92	67·1	63·3	60·3	·524	79	...	10	...	
4 30 ,,	29·92	67·4	63·5	60·4	·526	79	S.W.	10	...	Overcast; cirrostratus.
4 40 ,,	29·92	67·5	63·6	60·5	·528	78	...	10	...	Generally overcast; cirrostrat
4 50 ,,	29·92	66·9	63·4	60·6	·527	83	...	10	...	Balloon seen from top of Oc-gon Room; overcast.

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Meteorological Observations made at different Stations in connexion with the Balloon Ascent on

September 8 (*continued*).

ROYAL OBSERVATORY, GREENWICH.

Time of Observation.	Reading of			Temp. of the Dew-point.	Tension of Vapour.	Degree of Humidity.	Direction of Wind.	Amount of Cloud 0–10.	Amount of Ozone.	Remarks.
	Barom. reduced to 32° F.	Thermom.								
		Dry.	Wet.							
h m	in.	°	°	°	in.					
5 0 p.m.	29·92	66·4	63·2	60·6	·529	83	s.w.	10	...	Overcast. Balloon disappeared behind clouds at $4^h\ 55^m$. Saw the balloon due S., moving towards Eltham.
5 10 "	29·92	66·7	63·0	60·1	·520	80	...	9	...	Balloon seen for the last time. Overcast; cirrostratus.
5 20 "	29·92	65·7	63·0	60·9	·631	84	...	9	...	Clouds broken in S. and W.; cirrocumulus.
5 30 "	29·92	65·6	63·0	61·0	·537	85	s.w.	8	...	Cirrocumulus.
5 40 "	29·92	65·2	62·8	60·7	·531	85	...	8	...	
5 50 "	29·92	64·8	62·4	60·4	·526	86	...	6	...	
6 0 "	29·92	64·7	62·2	60·2	·522	86	s.w.	6	...	
6 10 "	29·92	64·2	62·0	60·2	·522	87	...	5	...	
6 20 "	29·93	64·0	62·0	60·3	·524	88	...	8	...	Cirrocumulus; sun shining on dome of Great Equatorial.
6 30 "	29·93	63·7	62·0	60·6	·529	90	s.w.	10	...	Overcast.
6 40 "	29·93	63·4	61·9	60·7	·531	91	...	10	...	Overcast; cirrocumulus, cumulus, and cirrostratus.
6 50 "	29·93	63·3	61·7	60·4	·526	90	...	10	...	
7 0 "	29·93	62·7	61·5	60·5	·528	94	s.s.w.	10	...	Overcast.

Report on the Theory of Numbers.—Part IV. *By* H. J. STEPHEN SMITH, *M.A., F.R.S., Savilian Professor of Geometry in the University of Oxford.*

105. *General Theorems relating to Composition.*—The theory of the composition of quadratic forms occupies an important place in the second part of the 5th section of the 'Disquisitiones Arithmeticæ,' and is the foundation of nearly all the investigations which follow it in that section. In accordance with the plan which we have followed in this portion of our Report, we shall now briefly resume the theory as it appears in the 'Disquisitiones Arithmeticæ,' directing our special attention to the additions which it has received from subsequent mathematicians. We premise a few general remarks on the Problem of composition.

If $F_1(x_1, x_2, \dots x_n)$ be a form of order m, containing n indeterminates, which, by a bipartite linear transformation of the type

$$\left.\begin{array}{l} x_\alpha = \Sigma\, a_{\alpha,\beta,\gamma}\, y_\beta\, z_\gamma, \\ \alpha = 1, 2, 3, \dots n, \\ \beta = 1, 2, 3, \dots n, \\ \gamma = 1, 2, 3, \dots n, \end{array}\right\},$$

is changed into the product of two forms $F_2(y_1, y_2, \ldots y_n)$ and $F_3(z_1, z_2, \ldots z_n)$ of the same order, and containing the same number of indeterminates, F_1 is said to be *transformable into the product of* F_2 *and* F_3; and, in particular, if the determinants of the matrix

$$\left| a_{\alpha, \beta, \gamma} \right|,$$

which is of the type $n \times n^2$, be relatively prime, F_1 is said to be *compounded of* F_2 *and* F_3. Adopting this definition, we may enunciate the theorem—"If F_1 be transformable into $F_2 \times F_3$, and if F_1, G_2, G_3 be contained in G_1, F_2, F_3 respectively, G_1 is transformable into $G_2 \times G_3$; and, in particular, if F_1 be compounded of F_2 and F_3, and the forms F_1, G_2, G_3 be equivalent to the forms G_1, F_2, F_3 respectively, G_1 is compounded of G_2 and G_3."

It is only in certain cases that the multiplication of two forms gives rise to a third form, transformable into their product. Supposing that F_2 and F_3 are irreducible forms, *i. e.* that neither of them is resoluble into rational factors, let I_1, I_2, I_3 be any corresponding invariants of F_1, F_2, F_3, and let us represent by B and C the determinants

$$\left| \frac{dx_\alpha}{dy_\beta} \right| \qquad \left. \begin{array}{l} \alpha=1, 2, 3, \ldots n, \\ \beta=1, 2, 3, \ldots n, \end{array} \right\} .$$

and

$$\left| \frac{dx_\alpha}{dz_\gamma} \right| \qquad \left. \begin{array}{l} \alpha=1, 2, 3, \ldots n, \\ \gamma=1, 2, 3, \ldots n, \end{array} \right\} ;$$

The transformation of F_1 into $F_2 \times F_3$ then gives rise to the relations

$$I_1 \times B^{\frac{mi}{n}} = I_2 \times F_3^{\,i}$$

$$I_1 \times C^{\frac{mi}{n}} = I_3 \times F_2^{\,i},$$

i denoting the order of the invariants I_1, I_2, I_3. If one of the two numbers I_2 and I_3 be different from zero, we infer that m is a divisor of n. For if $\frac{\mu}{\nu}$ be the fraction $\frac{m}{n}$ reduced to its lowest terms, the equations

$$I_1^{\nu} \times B^{\mu i} = I_2^{\nu} \times F_3^{\nu i}$$

$$I_1^{\nu} \times C^{\mu i} = I_3^{\nu} \times F_2^{\nu i};$$

imply that F_2 and F_3 (cleared of the greatest numerical divisors of all their terms) are perfect powers of the order μ; *i. e.*, $\mu=1$, or m divides n, since F_2 and F_3 are by hypothesis irreducible. We thus obtain the theorem (which however applies only to irreducible forms having at least one invariant different from zero)—"No form can be transformed into the product of two forms of the same sort, unless the number of its indeterminates is a multiple of its order." For example, there is no theory of composition for any binary forms, except quadratic forms, nor for any quadratic forms of an uneven number of indeterminates.

Again, when m is a divisor of n, let $n=km$, and let b, c, d_2, d_3 represent the greatest numerical divisors of B, C, F_2, F_3 respectively; we find

$$\frac{I_1}{I_2} = \left(\frac{d_3^{\,k}}{b} \right)^{\frac{mi}{n}}, \left(\frac{I_1}{I_3} \right) = \left(\frac{d_2^{\,k}}{c} \right)^{\frac{mi}{n}}, \frac{B}{b} = \left(\frac{F_3}{d_3} \right)^k, \frac{C}{c} = \left(\frac{F_2}{d_2} \right)^k.$$

The first two of these equations show that the invariants of the three forms F_1, F_2, F_3 are so related to one another, that we may imagine them to have been all derived by transformation from one and the same form (see Art. 80); the last two (which, it is to be observed, present an ambiguity of sign when $\frac{mi}{n}$ is even) show that the forms B and F_3^k, C and F_2^k, are respectively identical, if we omit a numerical factor.

Lastly, let Φ_1, Φ_2, Φ_3 be any corresponding covariants of F_1, F_2, F_3. The relation of covariance gives rise to the equations

$$\Phi_1(x_1, x_2, \dots x_n) \times B^{\frac{mp-q}{n}} = \Phi_2(y_1, y_2, \dots y_n) \times F_3^p(z_1, \dots z_n)$$

$$\Phi_1(x_1, x_2, \dots x_n) \times C^{\frac{mp-q}{n}} = \Phi_3(z_1, z_2, \dots z_n) \times F_2^p(y_1, \dots),$$

where p and q are the orders of the covariants in the coefficients and in the indeterminates respectively. Combining with these equations the values of B and C already given, we see that $\Phi_2 \times F_3^{\frac{q}{m}}$ and $\Phi_3 \times F_2^{\frac{q}{m}}$ are identical, excepting a numerical factor; *i. e.* that Φ_2 and Φ_3 are either identically zero, or else numerical multiples of powers of F_2 and F_3. If therefore two forms can be combined by multiplication so as to produce a third form transformable into their product, their covariants are all either identically zero or else are powers of the forms themselves. There is, consequently, no *general* theory of composition for any forms other than quadratic forms, because all other sorts of forms have covariants which cannot be supposed equal to zero, or to a multiple of a power of the form itself, without particularizing the nature of the form. And even as regards quadratic forms, we may infer that composition is possible only in cases of continually increasing particularity, as the number of indeterminates increases.

106. *Composition of Quadratic Forms.—Preliminary Lemmas.*—The following lemma is given by Gauss as a preliminary to the theory of the composition of binary quadratic forms (Disq. Arith., art. 234):—

(i.) "If the two matrices

$$\left|\begin{matrix}A\\B\end{matrix}\right| = \left|\begin{matrix}A_1 & A_2 & \dots & A_\mu\\ B_1 & B_2 & \dots & B_\mu\end{matrix}\right|$$

and

$$\left|\begin{matrix}a\\b\end{matrix}\right| = \left|\begin{matrix}a_1 & a_2 & \dots & a_\mu\\ b_1 & b_2 & \dots & b_\mu\end{matrix}\right|$$

be connected by the equation

$$\left|\begin{matrix}A\\B\end{matrix}\right| = k\left|\begin{matrix}a\\b\end{matrix}\right|,$$

in which the sign of equality refers to corresponding determinants in the two matrices; and if the determinants of $\left|\begin{matrix}a\\b\end{matrix}\right|$ admit of no common divisor beside unity; the equation

$$\left|\begin{matrix}A\\B\end{matrix}\right| = \left|k\right| \times \left|\begin{matrix}a\\b\end{matrix}\right|,$$

in which the sign of equality refers to corresponding constituents in the two matrices, is always satisfied by a matrix $|k|$ of the type 2×2, of which the determinant is k, and the constituents integral numbers."*

The subsequent analysis of Gauss can be much abbreviated if to this lemma we add three others.

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* For a generalization of this theorem, see a paper by M. Bazin, in Liouville, vol. xix. p. 209; or Phil. Trans. vol. cli. p. 295.

In their enunciations we represent by X, Y, x, y, four functions, homogeneous and linear in respect of each of the n binary sets, $\xi_1\,\eta_1$, $\xi_2\,\eta_2$, $\ldots\xi_n\,\eta_n$; by $\begin{vmatrix} A \\ B \end{vmatrix}$ and $\begin{vmatrix} a \\ b \end{vmatrix}$ the matrices composed of the coefficients of X, Y and x, y, respectively; by (P, Q, R), (P′, Q′, R′) quadratic forms of which the coefficients are any quantities whatever; and by k an integral number.

(ii.) "If X, Y, x, y, satisfy the n equations included in the formula

$$\frac{dX}{d\xi_i}\frac{dY}{d\eta_i}-\frac{dX}{d\eta_i}\frac{dY}{d\xi_i}=k\left(\frac{dx}{d\xi_i}\frac{dy}{d\eta_i}-\frac{dx}{d\eta_i}\frac{dy}{d\xi_i}\right),$$

the matrices $\begin{vmatrix} A \\ B \end{vmatrix}$ and $\begin{vmatrix} a \\ b \end{vmatrix}$ satisfy the equation

$$\begin{vmatrix} A \\ B \end{vmatrix}=k\begin{vmatrix} a \\ b \end{vmatrix}."$$

(iii.) "The greatest numerical common divisor of the n resultants

$$\frac{dX}{d\xi_i}\,\frac{dY}{d\eta_i}-\frac{dX}{d\eta_i}\,\frac{dY}{d\xi_i}$$

is equal to the greatest common divisor of the determinants of $\begin{vmatrix} A \\ B \end{vmatrix}$."

(iv.) "If the n resultants of X and Y be not all identically equal to zero, the equation $PX^2+2QXY+RY^2=P'X^2+2Q'XY+R'Y^2$ implies the equations $P=P'$, $Q=Q'$, $R=R'$."

107. *Gauss's Six Conclusions.*—Let F, f, f' represent the forms (A, B, C) $(X, Y)^2$, $(a, b, c)\ (x, y)^2$, $(a', b', c')\,(x', y')^2$, of which the determinants are D, d, d'; let also M, m, m' be the greatest common divisors of A, 2B, C, of a, $2b$, c, and of a', $2b'$, c'; $\mathfrak{M}$, $\mathfrak{m}$, $\mathfrak{m}'$, the greatest common divisors of A, B, C, of a, b, c, and of a', b', c', respectively. Supposing that F is transformed in $f \times f'$ by the substitution $X=p_0\,xx'+p_1\,xy'+p_2\,x'y+p_3\,yy'$, $Y=q_0\,xx'+q_1\,xy'+q_2\,x'y+q_3\,yy'$, let us represent the two resultants

$$\frac{dX}{dx}\frac{dY}{dy}-\frac{dX}{dy}\frac{dY}{dx} \text{ and } \frac{dX}{dx'}\frac{dY}{dy'}-\frac{dX}{dy'}\frac{dY}{dx'}$$

by Δ and Δ'; the six determinants of the matrix $\begin{vmatrix} p_0 & p_1 & p_2 & p_3 \\ q_0 & q_1 & q_2 & q_3 \end{vmatrix}$ (taken in their natural order) by P, Q, R, S, T, U; the greatest common divisor of these six numbers by k, and the greatest numerical common divisors of Δ and Δ' by δ and δ', so that (Lemma 3) k is the greatest common divisor of δ and δ'.

From the invariant property of the determinants of F, f and f' we infer

$$\Delta'^2=\frac{d'}{D}f^2,\quad \Delta^2=\frac{d}{D}f'^2,\ D\delta'^2=d'm^2,\ D\delta^2=dm'^2.$$

Hence *the quotients* $\frac{d}{D}$ *and* $\frac{d'}{D}$ *are squares.* (Gauss's 1st conclusion.) Also D *divides* $d'\mathfrak{m}^2$ *and* $d\mathfrak{m}'^2$. (Gauss's 2nd conclusion.) But k is the greatest common divisor of δ and δ'; therefore Dk^2 *is the greatest common divisor of* $d'\mathfrak{m}^2$ *and* $d\mathfrak{m}^2$. (Gauss's 4th conclusion.) Let $\frac{d}{D}=n^2$, $\frac{d'}{D}=n'^2$, and let the signs of n and n' be so taken that $\Delta'=n'f$, $\Delta=nf''$; these two equations are equivalent to the six following:—

$$\frac{P}{a}=\frac{R-S}{2b}=\frac{U}{c}=n';\quad \frac{Q}{a'}=\frac{R+S}{2b'}=\frac{T}{c'}=n. \quad \ldots\ldots \quad (\Omega.)$$

(Gauss's 3rd conclusion.)

Multiplying together the two resultants Δ and Δ', we obtain an identity, which we shall write at full:

$$\begin{aligned}
&[(p_0 q_1-p_1 q_0)x^2+(p_0 q_3-p_3 q_0+p_2 q_1-p_1 q_2)xy+(p_2 q_3-p_3 q_2)y^2]\\
&\times[(p_0 q_2-p_2 q_0)x'^2+(p_0 q_3-p_3 q_0+p_1 q_2-p_2 q_1)x'y'+(p_1 q_5-p_3 q_1)y'^2]\\
&=(q_1 q_2-q_0 q_3)\ (p_0 xx'+p_0 xy'+p_2 x'y+p_3 yy')^2\\
&+(q_0 p_3+p_0 q_3-q_1 p_2-q_2 p_1)(p_0 xx'+p_1 xy'+p_2 x'y+p_3 yy') \quad \ldots\ldots (\mathrm{I})\\
&\qquad\times(q_0 xx'+q_1 xy'+q_2 x'y+q_3 yy')\\
&+(p_1 p_2-p_0 p_3)(q_0 xx'+q_1 xy'+q_2 x'y+q_3 yy')^2.
\end{aligned}$$

Comparing this identity with the equation $\Delta\Delta'=nn'ff'=nn'\,\mathrm{F}$, we find by Lemma 4

$$\frac{q_1 q_2-q_0 q_3}{\mathrm{A}}=\frac{q_0 p_3+p_0 q_3-q_1 p_2-q_2 p_1}{2\mathrm{B}}=\frac{p_1 p_2-p_0 p_3}{\mathrm{C}}=nn' \quad \ldots (\Omega'.)$$

The 5th and 6th conclusions relate to the order of the form compounded of two given forms. The equation

$$\mathrm{AX}^2+2\mathrm{BXY}+\mathrm{CY}^2=(ax^2+2bxy+cy^2)\times(a'x'^2+2b'x'y'+c'y'^2)$$

shows that M divides mm'. But also mm' divides $\mathrm{M}k^2$. For operating on the equation just written with $\frac{d^2}{dx^2}$, $\frac{d^2}{dx\,dy}$, $\frac{d^2}{dy^2}$ successively, we find

$$\mathrm{A}\frac{d\mathrm{X}^2}{dx^2}+2\mathrm{B}\frac{d\mathrm{X}}{dx}\frac{d\mathrm{Y}}{dx}+\mathrm{C}\frac{d\mathrm{Y}^2}{dx^2}\equiv 0, \text{ mod } mm',$$

$$2\left[\mathrm{A}\frac{d\mathrm{X}}{dx}\frac{d\mathrm{X}}{dy}+\mathrm{B}\left(\frac{d\mathrm{X}}{dx}\frac{d\mathrm{Y}}{dy}+\frac{d\mathrm{X}}{dy}\frac{d\mathrm{Y}}{dx}\right)+\mathrm{C}\frac{d\mathrm{Y}}{dx}\frac{d\mathrm{Y}}{dy}\right]\equiv 0, \text{ mod } mm', \quad \ldots (j)$$

$$\mathrm{A}\frac{d\mathrm{X}^2}{dy^2}+2\mathrm{B}\frac{d\mathrm{X}}{dy}\frac{d\mathrm{Y}}{dy}+\mathrm{C}\frac{d\mathrm{Y}^2}{dy^2}\equiv 0, \text{ mod } mm'.$$

Whence $\mathrm{A}\Delta^2$, $2\mathrm{B}\Delta^2$, $\mathrm{C}\Delta^2$, and consequently $\mathrm{M}\delta^2$, are congruous to zero, mod mm'. Similarly $\mathrm{M}\delta'^2\equiv 0$, mod mm'; i.e. mm' divides $\mathrm{M}k^2$. If then $k=1$, i.e. *if* F *be compounded of* f *and* f', $\mathrm{M}=mm'$. (Gauss's 5th conclusion.)

Again, if in the congruences (j) we take $m'\mathfrak{m}$ as modulus instead of mm', we may omit the factor 2 in the second congruence, and may infer that $\mathrm{A}\Delta^2$, $\mathrm{B}\Delta^2$, $\mathrm{C}\Delta^2$ are all divisible by $m'\mathfrak{m}$, *i.e.* that $\mathfrak{m}m'$ divides $\mathfrak{M}k^2$, or $\mathfrak{M}$, when F is compounded of f and f. It is also readily seen that $\mathfrak{M}$ divides $m\mathfrak{m}'$ and $\mathfrak{m}m'$; whence observing that $\mathfrak{m}=m$ or $\frac{1}{2}m$, $\mathfrak{m}'=m'$ or $\frac{1}{2}m'$, $\mathfrak{M}=\mathrm{M}$ or $\frac{1}{2}\mathrm{M}$, according as f, f', and F are derived from properly or improperly primitive forms, we conclude that *if* f *and* f *be both derived from properly primitive forms, the form compounded of them is also derived from a properly primitive form; but if either* f *or* f *be derived from an improperly primitive form, the form compounded of them is derived from a similar form.* (Gauss's 6th conclusion.)

In the transformation of F into $f\times f'$, the form f is said to be taken directly or inversely, according as the fraction n is positive or negative. And similarly for f' and n'.

108. *Solution of the Problem of Composition.*—It appears from the identity (I) that if A, B, C, $p_0\ p_1\ p_2\ p_3$, $q_0\ q_1\ q_2\ q_3$, be integral numbers satisfying the nine equations (Ω), the form $(\mathrm{A}, \mathrm{B}, \mathrm{C})\ (\mathrm{X}, \mathrm{Y})^2$ will be transformed into the product of the two forms $(a, b, c)\ (x, y)^2$ and $(a', b', c')\ (x', y')^2$ by the substitution $\mathrm{X}=p_0 xx'+p_1 xy'+p_2 yx'+p_3 yy'_3$, $\mathrm{Y}=q_0 xx'+q_1 xy'+q_2 yx'+q_3 yy'$.

In order, therefore, to find a form, F, compounded directly or inversely of two given forms of which the determinants are to one another as two squares, we have to find eleven integral and two fractional numbers, satisfying the equations (Ω) and (Ω'), in which a, b, c, a', b', c', and the signs of n and n', are alone given; the numbers $p_0\,p_1\,p_2\,p_3$, $q_0\,q_1\,q_2\,q_3$, being further subject to the condition that the determinants of the matrix $\begin{vmatrix} p_0 & p_1 & p_2 & p_3 \\ q_0 & q_1 & q_2 & q_3 \end{vmatrix}$ are to admit of no common divisor. To determine n and n', we observe that the six determinants satisfy the identical relation $\mathrm{PU}-\mathrm{QT}+\mathrm{RS}=0$; from which we infer, first, that P, Q, R−S, R+S, T, U must be relatively prime, if P, Q, R, S, T, U are to be so; and secondly, substituting for the determinants their values given by the first six of the equations (Ω), that $dn'^2=d'n^2$. Denoting by δ' and δ the greatest common divisors of P, R−S, U and of Q, R+S, T, so that δ and δ' are relatively prime, we have evidently $n'=\pm\frac{\delta'}{m}$, $n=\pm\frac{\delta}{m'}$; the positive or negative signs being taken according as f' and f enter the composition directly or inversely; and the absolute values of δ and δ' being determined by the equation $\delta^2\,d'm^2=\delta'^2\,dm'^2$. The fractions n and n' being thus ascertained, the values of P, Q, R, S, T, U are known from the equations (Ω): these values are all integral: for P, Q, R−S, R+S, T, U, this is evident from the equations (Ω), and may be proved for R and S by means of the identity $\mathrm{PU}-\mathrm{QT}+\mathrm{RS}=0$. We have next to assign such values to the constituents of the matrix $\begin{vmatrix} p_0 & p_1 & p_2 & p_3 \\ q_0 & q_1 & q_2 & q_3 \end{vmatrix}$, that its determinants may acquire the known values of P, Q, R, S, T, U. To do so, it is sufficient* to obtain a *fundamental* set of solutions of the indeterminate system,

$$\left.\begin{array}{rrrr} & x_1\mathrm{U} & -x_2\,\mathrm{T} & +x_3\,\mathrm{S}=0 \\ -x_0\,\mathrm{U} & & +x_2\,\mathrm{R} & -x_3\,\mathrm{Q}=0 \\ x_0\,\mathrm{T} & -x_1\,\mathrm{R} & & +x_3\,\mathrm{P}=0 \\ -x_0\,\mathrm{S} & +x_1\,\mathrm{Q} & -x_2\,\mathrm{P} & =0 \end{array}\right\} \quad \ldots\ldots \quad (\mathrm{S}),$$

which is equivalent to only two independent equations. From the skew symmetrical form of the matrix of this system, it appears that if $\theta_0\,\theta_1\,\theta_2\,\theta_3$ be any multipliers whatever, any four numbers $(x_0\,x_1\,x_2\,x_3)$ proportional to

$$\left.\begin{array}{rrrr} & \theta_1\,\mathrm{P} & +\theta_2\,\mathrm{Q} & +\theta_3\,\mathrm{R} \\ -\theta_0\,\mathrm{P} & & +\theta_2\,\mathrm{S} & +\theta_3\,\mathrm{T} \\ -\theta_0\,\mathrm{Q} & -\theta_1\,\mathrm{S} & & +\theta_3\,\mathrm{U} \\ -\theta_0\,\mathrm{R} & -\theta_1\,\mathrm{T} & -\theta_2\,\mathrm{U} & \end{array}\right\} \quad \ldots\ldots \quad (\Sigma)$$

will satisfy the system (S), and in addition the equation

$$\theta_0\,x_0+\theta_1\,x_1+\theta_2\,x_2+\theta_3 x_3=0.$$

Assigning, then, to $\theta_0\,\theta_1\,\theta_2\,\theta_3$ any arbitrary values whatever, let $q_0\,q_1\,q_2\,q_3$ be four numbers relatively prime, and proportional to the four numbers (Σ); let also $\pi_0\,q_0+\pi_1\,q_1+\pi_2\,q_2+\pi_3\,q_3=1$; and employing $\pi_0\,\pi_1\,\pi_2\,\pi_3$ in the place of $\theta_1\,\theta_2\,\theta_2\,\theta_3$, let us represent by $p_0 p_1 p_2 p_2$ the solution of (S) thus obtained. We have thus two solutions of (S), satisfying respectively the relations

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* For a solution of the general problem, "To find all the matrices of a given type, of which the determinants have given values," see a paper by M. Bazin, in Liouville, vol. xvi. p. 145; or Phil. Trans. vol. cli. p. 302. For the definition of a *fundamental* set of solutions of an indeterminate system, see *ibid.* p. 297. It may be observed that the analysis of Gauss, which is exhibited in the text, is applicable to any matrix of the type $n\times(n+2)$.

$\pi_0 p_0 + \pi_1 p_1 + \pi_2 p_2 + \pi_3 p_3 = 0$, and $\pi_0 q_0 + \pi_1 q_1 + \pi_2 q_2 + \pi_3 q_3 = 1$, which prove that the two solutions form a fundamental set, *i.e.* that the determinants

$$\begin{vmatrix} p_0 p_1 p_2 p_3 \\ q_0\, q_1\, q_2\, q_3 \end{vmatrix} = [\mathrm{P, Q, R, S, T, U}].$$

It only remains to show that the values of A, B, C, which are now supplied by the equations (Ω'), are integral. Operating on the identity (I) with $\frac{d^2}{dx^2}$, $\frac{d^2}{dx\,dy}$, $\frac{d^2}{dy^2}$, and also with $\frac{d^2}{dx'^2}$, $\frac{d^2}{dx'dy'}$, $\frac{d^2}{dy'^2}$, we find, by reasoning similar to that which we have employed to establish the 5th conclusion, that $2\mathrm{A}nn'$, $2\mathrm{B}nn'$, $2\mathrm{C}nn'$, which are certainly integral numbers, are divisible by $2\delta\delta'$ if $\frac{\mathrm{R+S}}{\delta}$ and $\frac{\mathrm{R-S}}{\delta'}$ are both even, and by $\delta\delta'$ if either of these numbers is uneven. In the former case A, B, C are evidently integral; in the latter, either $\frac{2b}{m}$ or $\frac{2b'}{m'}$ is uneven, *i.e.* either m or m' is even, and the quotients of $2\mathrm{A}nn'$, $2\mathrm{B}nn'$, $2\mathrm{C}nn'$ divided by $\delta\delta'$ are $\frac{2\mathrm{A}}{mm'}$, $\frac{2\mathrm{B}}{mm'}$, $\frac{2\mathrm{C}}{mm'}$; whence, again, A, B, C are integral*.

109. *Composition of several Forms.*—It will now be convenient to extend the definition of composition to the case in which more than two forms are compounded. If a quadratic form, F, be changed by a substitution, linear in respect of n binary sets, into the product of n quadratic forms, $f_1 f_2 \ldots f_n$, so that $\mathrm{F}(\mathrm{X}, \mathrm{Y}) = \prod_{i=1}^{i=n} (a_i x_i^2 + 2bx_i y_i + c_i y_i^2)$, we shall say that F is transformable into $f_1 \times f_2 \times \ldots f_n$; and if the determinants of the matrix of the transformation are relatively prime, we shall say that F is compounded of $f_1, f_2, \ldots f_n$. We shall retain, with an obvious extension, the notation of Art. 107. The invariant property of the determinant of F supplies the n equations $\Delta_i^2 f_i^2 = \frac{d_i}{\mathrm{D}} [\Pi f]^2$; from which we infer (1) that D, d_1, d_2, . . . are to one another as square numbers, (2) that $\mathrm{D}k^2$ is the greatest common divisor of the n numbers $\frac{d_i}{m_i^2} \Pi m^2$. According as the equation $\Delta_i f_i = \sqrt{\frac{d_i}{\mathrm{D}}} . \Pi f$ is satisfied by a positive or negative value of the radical, we shall say that f_i is taken directly or inversely. Adopting this definition, we can enunciate the theorem—

"If F be compounded of $f_1, f_2, \ldots f_n$, and F′ be transformable into $f_1 \times f_2 \times \ldots \times f_n$, the forms being similarly taken in each case, F′ contains F." For we infer from (2) that $\mathrm{D}'k'^2 = \mathrm{D}$, whence $\Delta'_i = k'\Delta_i$, or by the Lemmas 2 and 1 of Art. 107, $\mathrm{X}' = \alpha\mathrm{X} + \beta\mathrm{Y}$, $\mathrm{Y}' = \gamma\mathrm{X} + \delta\mathrm{Y}$, $\alpha, \beta, \gamma, \delta$, denoting integral numbers which satisfy the equation $\alpha\delta - \beta\gamma = k'$. We thus obtain the equation $\mathrm{F}'(\alpha\mathrm{X} + \beta\mathrm{Y}, \gamma\mathrm{X} + \delta\mathrm{Y}) = \mathrm{F}(\mathrm{X}, \mathrm{Y})$, whence, by Lemma 4, F′ is transformed into F by $\begin{vmatrix} \alpha, \beta \\ \gamma, \delta \end{vmatrix}$.

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* Gauss shows that A, B, C are integral by substituting the values of $p_0 \ldots, q_0 \ldots$, in $q_1 q_2 - q_0 q_3$, $\frac{1}{2}(q_0 p_3 + p_0 q_3 - q_1 p_2 - p_1 q_2)$, $p_1 p_2 - p_0 p_3$, and observing that the results, after division by nn', are integral. The values of $p_0 \ldots$ are always obtained free from any common divisor by the process in the text; but Gauss has to determine four new multipliers $\theta_0\, \theta_1\, \theta_2\, \theta_3$, to obtain from the formulæ (Σ) the exact values of $q_0, \ldots$, and not equimultiples of those values. M. Schläfli (Crelle, vol. lvii. p. 170) has shown that Gauss's demonstration is connected with a remarkable symbolical formula.

If F be compounded of $f_1 f_2 \ldots f_n$, and a single transformation of F into $f_1 \times f_2 \times \ldots f_n$ be given, we may, by the same principles, find all the transformations of F into the product of $f_1 f_2, f_n$, taken as in the given transformation. For if $F(X_0, Y_0) = \Pi f$ represent the given transformation, and $F(X, Y) = \Pi f$ be any other transformation, we find $X = \alpha X_0 + \beta Y_0$, $Y = \gamma X_0 + \delta Y_0$, $\alpha\delta - \beta\gamma = +1$, and consequently $F(\alpha X_0 + \beta Y_0, \gamma X_0 + \delta \gamma_0) = F(X_0, Y_0)$; or $\begin{vmatrix} \alpha, \beta \\ \gamma, \delta \end{vmatrix}$ is, by Lemma 4, a proper automorphic of F. The formula $X = \alpha X_0 + \beta Y_0$, $Y = \gamma X_0 + \delta Y_0$, in which $\begin{vmatrix} \alpha, \beta \\ \gamma, \delta \end{vmatrix}$ is an automorphic of F, will therefore represent all the transformations required.

If F be transformable into $f_1 \times f_2 \times \ldots f_n$, and Φ contain F, while $f_1, f_2, \ldots f_n$ contain $\varphi_1, \varphi_2, \ldots \varphi_n$, Φ will be transformable into $\phi_1 \times \phi_2 \ldots \phi_n$. This follows from a preceding general observation (Art. 105); but we must add here that if T, τ_i denote positive or negative units, according as the transformations of Φ into F, and f_i into ϕ_i are proper or improper, while v_i denotes a positive or negative unit according as f_i is taken directly or inversely, ϕ_i will be taken directly or inversely according as $T \times \tau_i \times v_i$ is positive or negative. This is apparent if we observe that the sign of the quantity $\frac{f_i \Delta_i}{\Pi f}$ is altered by an improper transformation of X, Y, or x_i, y_i, but is not altered by a transformation of any of the other sets.

The theorem that "forms compounded of equivalent forms, similarly taken, are themselves equivalent" is included in the preceding. We may, therefore, speak of the class compounded of any number of given classes.

It is an important and not a self-evident proposition, that if F be compounded of $\phi, f_3, f_4, \ldots f_n$, and ϕ be compounded of f_1, f_2, F is compounded of $f_1, f_2, \ldots f_n$. Let $\phi = \alpha\xi^2 + 2\beta\xi\eta + \gamma\eta^2$, let μ be the greatest common divisor of α, 2β, γ, and ∇ the determinant of ϕ; let also X, Y transform F into $\phi \times f_3 \times f_4 \times \ldots \times f_n$. Writing in X and Y for ξ and η the bipartite expressions linear in $x_1 y_1, x_2 y_2$, by which ϕ is transformed into $f_1 \times f_2$, we obtain a transformation of F into $f_1 \times f_2 \times \ldots \times f_n$. If k be the greatest common divisor of the determinants of the matrix of this transformation, Dk^2 is the greatest common divisor of the n numbers $\frac{d_i}{m_i^2} \Pi m^2$. But this common divisor is the same as the greatest common divisor of $\nabla \times \prod_{i=3}^{i=n} m^2_i$, and the $n-2$ numbers

$$\frac{d_i \mu^2}{m_i^2} \prod_{s=3}^{s=n} m_s^2 \qquad i = 3, \ldots n;$$

because ∇ is the greatest common divisor of $d_1 m_2^2$ and $d_2 m_1^2$ (4th conclusion), and because $\mu = m_1 m_2$ (5th conclusion); *i. e.*, $Dk^2 = D$, or $k^2 = 1$, and F is compounded of $f_1, f_2, \ldots f_n$. Also, if $i > 2$, f_i is similarly taken in both compositions, for $\frac{\Delta_i f_i}{f_1 \times f_2 \times \ldots \times f_n}$ and $\frac{\Delta_i f_i}{\phi \times f_3 \times \ldots \times f_n}$ are identical; and if $i = 1$, or 2, $\Delta_i = \frac{dX}{dx_i}\frac{dY}{dy_i} - \frac{dX}{dy_i}\frac{dY}{dx_i} = \left(\frac{dX}{d\xi}\frac{dY}{d\eta} - \frac{dX}{d\eta}\frac{dY}{d\xi}\right) \times \left(\frac{d\xi}{dx_i}\frac{d\eta}{dy_i} - \frac{d\xi}{dy_i}\frac{d\eta}{dx_i}\right)$, whence if Ω and ω_i be positive or negative units, according as ϕ and f_i are taken directly or inversely in the composition of F and ϕ respectively, f_i will be taken directly or inversely in the composition of F according as $\Omega \times \omega_i$ is positive or negative.

By this theorem, the problem of finding a form compounded of any number of given forms is reduced to the problem of finding a form compounded of two given forms. For if $f_1 f_2 \ldots f_n$ be the given forms, we may compound the first with the second, the resulting form with the third, and so on until we have gone through all the forms, when the form finally obtained will be compounded of the given forms, as will immediately appear from successive applications of the preceding theorem. We also see that we may compound the forms in any order that we please, or we may divide them into sets in any way we please, and compounding first the forms of each set, afterwards compound the resulting forms. If any of the given forms are to be taken inversely, we may substitute for them their *opposites* (Art. 92) taken directly. We may thus, without any loss of generality, and with some gain in point of simplicity, avoid the consideration of inverse composition altogether; and, for the future, when we speak of the form compounded of given forms, or the class compounded of given classes, we shall understand the form or class compounded directly of the given forms or classes.

110. The solution of the problem of composition given in Art. 108 may be put into a form better suited to actual computation.

The system (S) is evidently satisfied by $[0, P, Q, R]$, and also by $[P, 0, -S, -T]$; and these solutions are independent, because the determinants of their matrix cannot all be zero unless $P=0$, a supposition which may be rejected as it implies that $a=0$, *i. e.* that d is a square. From this set of independent solutions a set of fundamental solutions is deduced, as follows. Let μ be the greatest common divisor of P, Q, R; and let k be determined by the congruences $k\frac{Q}{\mu}-S\equiv 0$, $k\frac{R}{\mu}-T\equiv 0$, mod $\frac{P}{\mu}$, which are simultaneously possible, because $\frac{Q}{\mu}$ and $\frac{R}{\mu}$ have no common divisor with the modulus, while the determinant $\frac{1}{\mu}(RS-QT)=-U\frac{P}{\mu}$ is divisible by it. The solutions $\left[\mu, k, \frac{kQ-\mu S}{P}, \frac{kR-\mu T}{P}\right]$, $\left[0, \frac{P}{\mu}, \frac{Q}{\mu}, \frac{R}{\mu}\right]$ are then a fundamental set, and may be taken for $[p_0\, p_1\, p_2\, p_3]$, $[q_0\, q_1\, q_2\, q_3]$ respectively. We thus find $Ann'=\frac{PQ}{\mu^2}$, or $A=\frac{a\,a'}{\mu^2}$; $2Bnn'=R+S-2k\frac{Q}{\mu}$. Multiplying this equation by $\frac{P}{\mu}$, $\frac{Q}{\mu}$, $\frac{R}{\mu}$ in succession, and attending to the congruences satisfied by k, we obtain the congruences $\frac{P}{\mu}B\equiv\frac{ab'}{\mu}$, $\frac{Q}{\mu}B\equiv\frac{a'b}{\mu}$, $\frac{R}{\mu}B\equiv\frac{bb'+Dnn'}{\mu}$, mod A; which determine B, for the modulus A, because $\frac{P}{\mu}$, $\frac{Q}{\mu}$, $\frac{R}{\mu}$ are relatively prime. These determinations [viz. of A, and of B, mod A] are sufficient for our purpose; because if $B'=B+\lambda A$, the forms $\left(A, B, \frac{B^2-D}{A}\right)$ and $\left(A, B', \frac{B'^2-D}{A}\right)$ are equivalent. To obtain, therefore, the form compounded of two given forms (a, b, c), (a', b', c'), we first take the greatest common divisor of $d'\,m^2$ and $d\,m'^2$ for D (giving to D the sign of d or d'); we then determine n and n'

by the equations $n=\sqrt{\frac{d}{\mathrm{D}}}$, $n'=\sqrt{\frac{d'}{\mathrm{D}}}$, and, representing by μ the greatest common divisor of an', $a'n$, $bn'+b'n$, we obtain A, B, C from the system

$$\mathrm{A}=\frac{a\,a'}{\mu^2}$$

$$\left.\begin{aligned}\frac{an'}{\mu}\,\mathrm{B}&\equiv\frac{ab'}{\mu}\\ \frac{a'n}{\mu}\,\mathrm{B}&\equiv\frac{a'b}{\mu}\\ \frac{bn'+b'n}{\mu}\,\mathrm{B}&\equiv\frac{bb'+\mathrm{D}nn'}{\mu}\end{aligned}\right\}\text{mod A}.$$

$$\mathrm{C}=\frac{\mathrm{B}^2-\mathrm{D}}{\mathrm{A}}$$

These formulæ, which are applicable to every case of composition, and are therefore more general than the analogous formulæ given by Gauss (Disq. Arith., art. 243), are due to M. Arndt*, who has also given an independent investigation of them, though our limits have compelled us here to deduce them from Gauss's general solution of the problem of composition. That (A, B, C) is transformed into $(a, b, c)\times(a'\,b'\,c')$ by the substitution

$$\begin{aligned}\frac{1}{\mu}\,\mathrm{X}&=xx'+\frac{b'-\mathrm{B}n'}{a'}\,xy'+\frac{b-\mathrm{B}n}{a}\,x'y+\frac{bb'+\mathrm{D}nn'-\mathrm{B}(bn'+b'n)}{aa'}\,yy',\\ \mu\mathrm{Y}&=\qquad an'\,xy'+a'n\,x'y+(b'n+bn')yy',\end{aligned}$$

may be inferred from the values of $p_0, \ldots q_0, \ldots$; or may be verified directly by observing that

$$\mu[\mathrm{AX}+(\mathrm{B}+\sqrt{\mathrm{D}})\mathrm{Y}]=[ax+(b+n\sqrt{\mathrm{D}})y]\times[a'x'+(b'+n'\sqrt{\mathrm{D}})y'].$$

111. *Composition of Forms—Method of Dirichlet.*—Lejeune Dirichlet, in an academic dissertation ("De formarum binariarum secundi gradus compositione," Crelle, vol. xlvii. p. 155), has deduced the theory of the composition of forms from that of the representation of numbers. The principles of this method are applicable to any case of composition; but Dirichlet has restricted his investigation to properly primitive forms of the same determinant D. Let (a, b, c), (a', b', c') be two such forms; let M and M' be two numbers prime to 2D, and capable of the primitive representations $\mathrm{M}=am^2+2bmn+cn^2$, $\mathrm{M}'=a'm'^2+2b'm'n'+c'n'^2$, by the forms (a, b, c) and (a', b', c') respectively; also let these representations appertain to the values ω and ω' of $\sqrt{\mathrm{D}}$, so that $\omega^2\equiv\mathrm{D}$, mod M, $\omega'^2\equiv\mathrm{D}$, mod M', and so that the forms (a, b, c), (a', b', c') are respectively equivalent to the forms $\left(\mathrm{M}, \omega, \frac{\omega^2-\mathrm{D}}{\mathrm{M}}\right)$,

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* Crelle's Journal, vol. lvi. p. 64. In the new edition of the Disq. Arith. (Göttingen, 1863), a MS. note of Gauss is printed at p. 263, containing the congruences by which B is determined in the case of the direct composition of two forms of the same determinant.

The account of the theory of composition in the preceding articles (106–109) differs from that in the Disq. Arith. (arts. 234–243) chiefly in the use which is here made of the invariant property of the determinant. A different mode of treatment of Gauss's analysis is adopted by M. Bazin, in Liouville, vol. xvi. p. 161.

In Arts. 108 and 110 we have endeavoured to supply the analysis of a problem which Gauss, as is not unusual with him, has treated in a purely synthetical manner (Disq. Arith., arts. 236 and 242, 243); and it is for this reason that we have introduced the consideration of *fundamental* sets of solutions of indeterminate systems, which are not explicitly mentioned in the Disq. Arith. It is perhaps singular that Gauss does not employ the identity PU−QT+RS=0; it was first given by M. Poullet Delisle, in a note on Art. 235 in his translation of the Disq. Arith.

$\left(\mathrm{M}', \omega', \frac{\omega'^2-\mathrm{D}}{\mathrm{M}'}\right)$. If the values ω and ω' are *concordant, i. e.* if it is possible to find a number Ω satisfying the three congruences $\Omega^2\equiv\mathrm{D}$, mod MM', $\Omega\equiv\omega$, mod M, $\Omega\equiv\omega'$, mod M′ (in which case the solution Ω of the congruence $\Omega^2\equiv\mathrm{D}$, mod MM', may be said to *comprehend* the solutions ω and ω' of the congruences $\omega^2\equiv\mathrm{D}$, mod M, and $\omega'^2\equiv\mathrm{D}$, mod M′), the form $\left(\mathrm{MM}', \Omega, \frac{\Omega^2-\mathrm{D}}{\mathrm{MM}'}\right)$ will be a properly primitive form of determinant D, and will belong to one and the same class (which may be termed the class compounded of the classes containing (a, b, c) and (a', b', c')) whatever two numbers (subject to the conditions prescribed) are taken for M and M′. To prove this, a few preliminary remarks are necessary. (1.) If the solutions ω and ω' are concordant, there is but one solution Ω (incongruous mod MM′) comprehending them. (2.) The necessary and sufficient condition for the concordance of ω and ω' is $\omega\equiv\omega'$, for every prime modulus dividing both M and M′. (3.) If Ω, ω, ω' satisfy the congruence $x^2\equiv\mathrm{D}$ for the modules MM′, M, and M′ respectively; and if, besides, $\Omega\equiv\omega$, $\Omega\equiv\omega'$, for every prime divisor of M and M′ respectively, ω and ω' are concordant, and Ω is the solution comprehending them. (4.) The value of $\sqrt{\mathrm{D}}$ to which any given primitive representation (such as $\mathrm{M}=am^2+2bmn+cn^2$) appertains, may be defined by congruences, without employing the numbers μ and ν which satisfy the equation $m\nu-n\mu=1$ (see Art. 86); in fact, we find $am+(b+\omega)n\equiv0$, mod M, $(b-\omega)m+cn\equiv0$, mod M; whence also $\omega\equiv-b$, mod d, $\omega\equiv+b$, mod d', if d and d' are common divisors of M and m and of M and n.

We may suppose that the given forms (a, b, c) and (a', b', c') are so prepared* that the representations of a and a' by them appertain to concordant values of $\sqrt{\mathrm{D}}$; *i. e.* that we can find a number B satisfying the congruences $\mathrm{B}^2\equiv\mathrm{D}$, mod aa', $\mathrm{B}\equiv b$, mod a, $\mathrm{B}\equiv b'$, mod a'. Let $\frac{\mathrm{B}^2-\mathrm{D}}{aa'}=\mathrm{C}$; the forms (a, b, c), (a', b', c') are then equivalent to $(a, \mathrm{B}, a'\mathrm{C})$, $(a', \mathrm{B}, a\mathrm{C})$ respectively; and if $\mathrm{X}=xx'-\mathrm{C}yy'$, $\mathrm{Y}=axy'+a'x'y+2\mathrm{B}yy'$, we find by actual multiplication $aa'\mathrm{X}^2+2\mathrm{BXY}+\mathrm{CY}^2=(ax^2+2\mathrm{B}xy+a'\mathrm{C}y^2)\times(a'x'^2+2\mathrm{B}x'y'+a\mathrm{C}x'^2)$. From this equation (which is included as a particular case in the formulæ of M. Arndt) it appears that MM′ is capable of representation by $(aa', \mathrm{B}, \mathrm{C})$; it can also be shown (1) that this representation is primitive; (2) that it appertains to a value of $\sqrt{\mathrm{D}}$, mod MM′, comprehending the values ω and ω', to which the representations of M and M′ by (a, b, c) and (a', b', c') respectively appertain. (1.) If x, y, x', y', and X, Y are the values of the indeterminates in the representations of M, M′, and MM′ by $(a, \mathrm{B}, a'\mathrm{C})$, $(a', \mathrm{B}, a\mathrm{C})$ and $(aa', \mathrm{B}, \mathrm{C})$, the hypothesis that X and Y admit of a common prime divisor p is expressed by the simultaneous congruences $xx'-\mathrm{C}yy'\equiv0$, $axy'+a'x'y+2\mathrm{B}yy'\equiv0$, mod p. These congruences are linear in respect of the relatively prime numbers x' and y'; their coexistence implies, therefore, that p divides their determinant M; similarly it may be shown that p divides M′; so that $\omega\equiv\omega'$, mod p, because ω and ω' are concordant. The congruences satisfied by ω and ω' now give the relations $ax+(\mathrm{B}+\omega)y\equiv0$,

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* It is readily proved that a properly primitive form can represent numbers prime to any given number; thus a form can always be found equivalent to a given properly primitive form, and having its first coefficient prime to a given number. This transformation will be frequently employed in the sequel. . . . In the present instance, we have only to substitute for the given forms any two forms respectively equivalent to them and having their first coefficients relatively prime.

$a'x'+(B+\omega)y'\equiv 0$, mod p; whence, eliminating x and x' from the congruence $Y\equiv 0$, and observing that 2ω is prime to M and therefore to p, we find $yy'\equiv 0$, mod p. If y is divisible by p, we infer, from the congruence $X\equiv 0$, that x' is also divisible by p; but the congruences satisfied by ω and ω' give in this case the contradictory results $\omega\equiv +B$, $\omega\equiv -B$; i. e. y is not divisible by p, and similarly it may be shown that y' is not divisible by p. The congruence $yy'\equiv 0$, mod p, is therefore impossible; or the representation of MM′ by (aa', B, C) is primitive. (2.) Let Ω' be the value of $\sqrt{D}$, to which this representation appertains; and let p be any divisor of M; then Ω' satisfies the congruences $aa'X+(B+\Omega')Y\equiv 0$, $(B-\Omega')X+CY\equiv 0$, mod p; and it will be found, on substituting the values of X and Y, that these congruences are also satisfied by ω; whence it follows, since either X or Y is prime to p, that $\Omega'\equiv\omega$, mod p. Similarly, if p be a prime divisor of M′, $\Omega'\equiv\omega'$, mod p; or Ω' is a solution of the congruence $\Omega'^2\equiv D$, mod MM′, comprehending the solutions ω and ω'. Hence $\Omega'\equiv\Omega$, mod MM′, and the form $\left(MM', \Omega, \frac{\Omega^2-D}{MM'}\right)$ is equivalent to (aa', B, C), because either of them is equivalent to $\left(MM', \Omega', \frac{\Omega'^2-D}{MM'}\right)$. The equivalence of all the forms included in the expression $\left(MM', \Omega, \frac{\Omega^2-D}{MM'}\right)$ is therefore demonstrated.

It will be seen that Dirichlet's method may be applied to the composition of any number of forms, and that the theorems of Art. 109 present themselves as immediate consequences of his definition of composition.

112. *Composition of Classes of the same Determinant.*—We shall now consider more particularly the composition of classes of the same determinant D. We represent these classes by the letters f, ϕ, . . . , and we use the signs of equality and of multiplication to denote equivalence and composition respectively *. The following theorems are then immediately deducible from the six conclusions of Art. 107, and from the formulæ of Art. 110.

(i.) "If f be a properly primitive class, $f\times\Phi$ is of the same order as Φ."

(ii.) "A class is unchanged by composition with the principal class." In consequence of this property, it is sometimes convenient to represent the principal class by 1.

(iii.) "The composition of two opposite† properly primitive classes produces the principal class."

If, then, f denote any properly primitive class, we may denote its opposite by f^{-1}, and we may write $f\times f^{-1}=1$.

(iv.) "If f be a given properly primitive class, and Φ any given class, the equation $F\times f=\Phi$ is always satisfied by one class, F, and by one only; viz. by the class $F=\Phi\times f^{-1}$."

(v.) "If Φ_1, Φ_2, . . be all different classes, and f be a properly primitive class, $f\times\Phi_1$, $f\times\Phi_2$, . . are all different classes."

(vi.) "A properly primitive ambiguous class produces by its duplication the principal class;" for an ambiguous class is its own opposite. Conversely, if $\phi^2=1$, *i. e.* if ϕ be a class which, by its duplication, produces the principal class, ϕ is a properly primitive ambiguous class; for we find $\phi^2\times\phi^{-1}=\phi^{-1}$, whence $\phi=\phi^{-1}$, or ϕ and its opposite are properly equivalent.

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* Gauss uses the sign of addition instead of that of multiplication; thus $f\times\phi$ is $f+\phi$ in the Disq. Arith., and f^n is nf. The change appears to have been introduced by his French translator, and to have been acquiesced in by subsequent writers.

† Two classes which are improperly equivalent are called opposite, because they contain opposite forms (see Art. 92).

(vii.) "The class compounded of the opposites of two or more forms is the opposite of the class compounded of those forms." It follows from this, or from vi., that a class compounded of ambiguous classes is itself ambiguous.

(viii.) Let $\Phi_0, \Phi_1, \ldots \Phi_{\omega-1}$ represent all the classes of det. D, and of a given order Ω; and let $1, f_1, f_2, \ldots f_{n-1}$ represent the properly primitive classes of the same determinant; it may then be shown that ω is a divisor of n, and that, given two classes of the order Ω, there always exist $\frac{n}{\omega}$ properly primitive classes, which, compounded with one of them, produce the other. Assuming, for a moment, that a form Φ_0 exists, such that the ω equations included in the formula $\Phi_0 \times f = \Phi_\mu$ can all be satisfied, we see that each of these equations is satisfied by the same number of properly primitive classes f; for if the equation $\Phi_0 \times f = \Phi_0$ be satisfied by k primitive classes, $1, \phi_1, \phi_2, \ldots \phi_{k-1}$, the equation $\Phi_0 \times f = \Phi_\mu$, which is, by hypothesis, satisfied by a single class, f_μ, is also satisfied by the $k-1$ classes $f_\mu \times \phi_1, \ldots f_\mu \times \phi_{k-1}$, but by no other class. Since, then, the classes $\Phi_0 \times f$, of which the number is n, represent every class of the order Ω k times, we have evidently $n = k\omega$. It is also readily seen that every equation of the type $\Phi_\nu \times f = \Phi_\mu$ admits of k solutions; and thus it only remains to justify the assumption on which the preceding proof depends. If the order Ω be derived by the multiplier m from a properly primitive class of determinant $\Delta = \frac{D}{m^2}$, we may take for Φ_0 the class represented by the form $(m, 0, -\Delta m)$; if Ω be derived from an improperly primitive class, we take for Φ_0 the class represented by the form $\left(2m, m, -m\frac{\Delta-1}{2}\right)$. Representing Φ_μ in the first case by the form (ma, mb, mc), and in the second by the form $(2ma, mb, 2mc)$, and supposing (as we may do) that a in each case is prime to 2D, we see that the forms (a, mb, m^2c) and $(a, bm, 4cm^2)$ are properly primitive; and we find by the formulæ of composition (Art. 110),

$$(m, 0, -\Delta m) \times (a, bm, cm^2) = (ma, mb, mc)$$

$$\left(2m, m, -m\frac{\Delta-1}{2}\right) \times (a, bm, 4cm^2) = (2ma, mb, 2mc);$$

i. e. the equation $\Phi_0 \times f = \Phi_\mu$ can be satisfied for every value of μ.

113. *Comparison of the numbers of Classes of different Orders.*—To determine the quotient $\frac{n}{\omega}$ of the last article, Gauss investigates the properly primitive classes of det. D, which, compounded with the classes $(m, 0, -\Delta m)$ and $\left(2m, m, -m\frac{\Delta-1}{2}\right)$, reproduce those classes themselves. He thus employs the theory of composition to compare the number of properly primitive classes of a given determinant with the number of classes contained in any other order of the same determinant; or, which comes to the same thing, to compare the numbers of classes, of any given orders, of two determinants which are to one another as square numbers (Disq. Arith., art. 253-256). We have already seen (Art. 103) that the infinitesimal analysis of Dirichlet supplies a complete solution of this problem; whereas, in the case of a positive determinant, the result in its simplest form was not obtained by Gauss. It has, however, been recently shown by M. Lipschitz (Crelle, vol. liii. p. 238) that the formulæ of Dirichlet may be deduced, in a very elementary manner, from the theory of transformation. We propose in this

place to give an account of this investigation, and to point out its relation to the method pursued by Gauss. We begin with the theorem

"Every properly primitive class of determinant De^2 is contained in one, and only one, properly primitive class of determinant D."

Let (A, B, C) be a properly primitive form of det. De^2, in which A is prime to e; let B′ be determined by the congruence $eB' \equiv B$, mod A, and C′ by the equation $C' = \frac{B'^2 - D}{A}$; then the forms (A, B, C) and ($A, B'e, C'e^2$) are equivalent; but ($A, B'e, C'e^2$) is contained in (A, B′, C′), therefore also (A, B, C) is contained in (A, B′, C′), that is, in a properly primitive form of determinant D. Again, if (a, b, c), (a', b', c') are two forms of det. D, each containing (A, B, C), these two forms are equivalent. For applying to (A, B, C) the system of transformations of modulus e, included in the formula $\begin{vmatrix} m, & k \\ 0, & \mu \end{vmatrix}$ (art. 88), we readily find that, of the resulting forms, one, and only one, will have its coefficients divisible by e^2*; therefore the class represented by (A, B, C) contains one, and only one class of det. De^4, and of the type (e^2p, e^2q, e^2r). But, applying to (A, B, C) the transformations inverse to those by which (a, b, c) and (a', b', c') are changed into (A, B, C), (A, B, C) is changed into (e^2a, e^2b, e^2c) and (e^2a', e^2b', e^2c'); these two forms are therefore equivalent; *i. e.* (a, b, c) and (a', b', c') are equivalent.

We have next to ascertain how many different properly primitive classes of determinant De^2 are contained in the class represented by (a, b, c), a properly primitive form of det. D, in which a may be supposed prime to e. Applying to (a, b, c) a complete system of transformations of modulus e, we inquire in the first place how many of the resulting forms are properly primitive. For this purpose we observe that if $e = e_1 \times e_2 \times e_3 \times \ldots$ ($e_1, e_2, \ldots$ representing factors of which no two have any common divisor), a complete system of transformations for the modulus e is obtained by compounding, in any definite order, the systems of transformations for the modules $e_1, e_2, \ldots$; *i.e.* if $| e_1 |, | e_2 |, \ldots$ be symbols representing complete systems of transformations for the modules $e_1, e_2, \ldots$, every transformation of modulus e is equivalent by post-multiplication† to one and only one of the transformations $| e_1 | \times | e_2 | \times | e_3 | \times \ldots$ It will, therefore, be sufficient to determine the number of properly primitive forms obtained by applying to a properly primitive form a complete system of transformations for a modulus which is the power of a prime. Let p be an uneven prime, and let (a, b, c) be changed into (A, B, C) by $\begin{vmatrix} p^{\alpha-\gamma}, & k \\ 0, & p^{\gamma} \end{vmatrix}$, a formula which will represent a complete system of transformations for the modulus p^{α}, if γ receive every value from 0 to α inclusive, and if k be the general term of a complete system of residues, mod $p^{\alpha-\gamma}$; we find

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* If $\begin{vmatrix} m, & k \\ 0, & \mu \end{vmatrix}$ transform (A, B, C) into (P, Q, R), we have

$$P = Am^2,\ Q = m(Ak + B\mu),\ R = Ak^2 + 2Bk\mu + C\mu^2.$$

Observing that A is prime to e, we infer from the congruence $P \equiv 0$, mod. e^2, that $m = e$, $\mu = 1$; the congruence $Q \equiv 0$, mod. e^2, then becomes $Ak + B \equiv 0$, mod. e, giving one, and only one, value of k mod. e; and this value satisfies the remaining congruence $R \equiv 0$, mod. e^2, since

$$AR = (Ak + B)^2 - De^2.$$

† If | A | and | B | are two transformations connected by the symbolic equation

$$| B | = | A | \times | V |,$$

in which | V | is a unit transformation, | A | and | B | are said to be equivalent by post-multiplication, or to belong to the same set. A complete system of transformations for any modulus contains one transformation belonging to each set.

$$A=ap^{2(\alpha-\gamma)},\ B=(ak+bp^{\gamma})p^{\alpha-\gamma},\ C=ak^2+2bkp^{\gamma}+cp^{2\gamma};$$

whence, if $\gamma=\alpha$, (A, B, C) is properly primitive; and is so, or not, for every other value of γ, according as C is not, or is, divisible by p. If $\gamma=0$, we have $C\equiv 0$, for $p^{\alpha-1}\left[1+\left(\frac{D}{p}\right)\right]$ values of k, incongruous mod. p^{α}; if γ have any value intermediate between 0 and α, we have $C\equiv 0$, for $p^{\alpha-\gamma-1}$ values of k, incongruous mod. $p^{\alpha-\gamma}$. Hence the number of properly primitive forms is

$$[1+p+p^2+\ldots+p^{\alpha}]-p^{\alpha-1}\left[1+\left(\frac{D}{p}\right)\right]$$
$$-[p^{\alpha-2}+p^{\alpha-3}+\ldots+1]=p^{\alpha}\left[1-\frac{1}{p}\left(\frac{D}{p}\right)\right];$$

and similarly if $p=2$ it will be found that the number of properly primitive forms is 2^{α}. Hence the number N of properly primitive forms, arising from the application of a complete system of transformations of modulus e to the form (a, b, c), is $e\Pi\left[1-\frac{1}{p}\left(\frac{D}{p}\right)\right]$, p denoting any uneven prime dividing e. It remains to determine the number of non-equivalent classes in which these N forms are contained. For brevity, we consider the case of a positive determinant. Let $[T_x, U_x]$ represent any solution of the equation $T^2-DU^2=1$, and let σ be the index of the least solution of that equation which is also a solution of $T^2-e^2DU^2=1$, *i. e.* let σ be the index of the first number in the series $U_1, U_2, \ldots$ which is divisible by e; also let (A, B, C) represent any one of the N properly primitive forms into which (a, b, c) is transformed. The transformations of modulus e by which (a, b, c) is changed into (A, B, C) belong to σ different sets, the transformations of the same set being equivalent by postmultiplication, but those of different sets not being so equivalent. For if $\begin{vmatrix}\alpha, & \beta\\ \gamma, & \delta\end{vmatrix}$ be a transformation of (a, b, c) into (A, B, C), any other transformation is represented (Art. 89) by the formula

$$\begin{vmatrix}T_x-bU_x, & -cU_x\\ aU_x\ \ , & T_x+bU_x\end{vmatrix}\times\begin{vmatrix}\alpha, & \beta\\ \gamma, & \delta\end{vmatrix},$$

and these two transformations will or will not belong to the same set, according as a unit transformation $\begin{vmatrix}\lambda, & \mu\\ \nu, & \rho\end{vmatrix}$, satisfying the equation

$$\begin{vmatrix}\alpha, & \beta\\ \gamma, & \delta\end{vmatrix}\times\begin{vmatrix}\lambda, & \mu\\ \nu, & \rho\end{vmatrix}=\begin{vmatrix}T_x-bU_x, & -cU_x\\ aU_x, & T_x+bU_x\end{vmatrix}\times\begin{vmatrix}\alpha, & \beta\\ \gamma, & \delta\end{vmatrix},$$

does or does not exist. Premultiplying each side of this equation by $\begin{vmatrix}\delta, & -\beta\\ -\gamma, & \alpha\end{vmatrix}$, we find

$$e\times\begin{vmatrix}\lambda, & \mu\\ \nu, & \rho\end{vmatrix}=\begin{vmatrix}eT_x-BU_x, & -CU_x\\ AU_x, & eT_x+BU_x\end{vmatrix},$$

whence, observing that A, B, C are relatively prime, we see that λ, μ, ν, ρ are or are not integral according as U_x is, or is not, divisible by e; a conclusion which implies that the transformations of (a, b, c) into (A, B, C) are contained in σ different sets. It thus appears that, of the N transformations, which applied to (a, b, c) give properly primitive forms, there are σ which give forms equivalent to (A, B, C); *i. e.* the number of properly primitive classes of det. De^2, contained in (a, b, c), a properly primitive class of det. D, is $\frac{N}{\sigma}=\frac{e}{\sigma}\Pi\left[1-\frac{1}{p}\left(\frac{D}{p}\right)\right]$; a result which is in accordance with the formula of Dirichlet (Art. 103). If D be negative, we have only to put $\sigma=1$, as is sufficiently apparent from the preceding proof; if, however, $D=-1$, $\sigma=2$.

The properly primitive classes of det. De^2, into which a given properly primitive class (a, b, c) of det. D is transformable, are always such that, compounded with the class $(e, 0, -De)$, they produce the class (ea, eb, ec). For let (a, b, c) be transformable into (A, B, C) of det. De^2, and let us take a form of the type $(A, B'e, C'e^2)$, equivalent to (A, B, C); then (a, b, c) and (A, B', C') are equivalent. But $(e, o, -De)\times(A, B'e, C'e^2)=(eA, eB', eC')$, therefore also $(e, 0, -De)\times(A, B, C)=(ea, eb, ec)$. And conversely the classes which, compounded with $(e, 0, -De)$, produce (ea, eb, ec) are precisely the classes into which (a, b, c) is transformable. Thus the properly primitive classes of det. De^2, which compounded with $(e, 0, -De)$ reproduce that class itself, are no other than the properly primitive classes of det. De^2 into which $(1, 0, -D)$ is transformable. And it is by this substitution of a problem of transformation for a problem of composition that M. Lipschitz has simplified and completed the analysis of Gauss.

A method similar in principle is applicable to the comparison of the numbers of properly and improperly primitive classes. We can first show that if $D\equiv1$, mod. 4, the double of every properly primitive class of det. D arises by a transformation of modulus 2 from one, and only one, improperly primitive class of the same determinant; viz. if (a, b, c) is a given properly primitive form, in which a and b are uneven, $\left(2a, b, \frac{c}{2}\right)$ is improperly primitive, and is changed into $(2a, 2b, 2c)$ by $\begin{vmatrix}1, 0\\0, 2\end{vmatrix}$; and, again, if $(2p, q, 2r)$, $(2p', q', 2r')$ are two improperly primitive forms, each of which is transformable into $(2a, 2b, 2c)$, these two forms are equivalent, because (a, b, c) is transformable into $(4p, 2q, 4r)$ and also into $(4p', 2q', 4r')$, while it can be shown that (a, b, c) is transformable into the double of only one improperly primitive class. Also, applying the system of transformations, $\begin{vmatrix}1, 0\\0, 2\end{vmatrix}$, $\begin{vmatrix}2, 0\\0, 1\end{vmatrix}$, $\begin{vmatrix}2, 1\\0, 1\end{vmatrix}$, to the improperly primitive form $(2p, q, 2r)$, we obtain, if $D\equiv1$, mod. 8, the double of only one properly primitive form: in this case therefore the numbers of properly and improperly primitive classes are equal. If $D\equiv5$, mod. 8, we obtain the doubles of three properly primitive forms; and we have to decide to how many different classes these three forms belong. It appears from Art. 89, that if $\begin{vmatrix}\alpha, \beta\\\gamma, \delta\end{vmatrix}$ be a transformation of $(2p, q, 2r)$ into the double of a properly primitive form (a, b, c), all the transformations are included in the formula

$$\begin{vmatrix}\frac{1}{2}(T_x-qU_x), & -rU_x\\ pU_x, & \frac{1}{2}(T_x+qU_x)\end{vmatrix}\times\begin{vmatrix}\alpha, \beta\\\gamma, \delta\end{vmatrix},$$

$[T_x, U_x]$ denoting any solution of the equation $T^2-DU^2=4$. Taking the case of a positive determinant, and employing the same reasoning as before, we infer that if U_σ be the first of the numbers $U_1, U_2, \ldots$ which is even, these transformations are contained in σ different sets. But σ is either 1 or 3 according as U_1 is even or uneven (see Art. 96, vi.); the three forms will therefore represent three classes or one, according as U_1 is even or uneven; and the number of properly primitive classes, in these two cases respectively, will be three times the number of improperly primitive classes, or equal to it. If D be negative, the three forms will belong to different classes; and there will be three times as many properly as improperly primitive classes. From this statement, however, we must except the determinant -3, which has one properly and one improperly primitive class.

It will be found that the properly primitive class or classes, into the double of which a given improperly primitive class can be transformed, and which in turn can be transformed into the double of the given class, are also the class or classes which compounded with the class $\left(2, 0, -\frac{D-1}{2}\right)$ produce the given class. Thus every improperly primitive class is connected either with one or three properly primitive classes (see Art. 98, note, and Art. 118).

114. *Composition of Genera.*—Let f and f' be two properly primitive classes of det. D, m and m' two numbers prime to one another and to 2D, and represented by f and f' respectively; then mm' is represented by $f \times f'$. Hence the generic character of $f \times f'$ is obtained by multiplying together the values of the particular characters of f and f'. For those generic characters which are expressed by quadratic symbols this is evident, since

$$\left(\frac{mm'}{p}\right) = \left(\frac{m}{p}\right) \times \left(\frac{m'}{p}\right);$$

and it is equally true for the supplementary characters, since it will be found that

$$(-1)^{\frac{mm'-1}{2}} = (-1)^{\frac{m-1}{2}} \times (-1)^{\frac{m'-1}{2}}, \quad (-1)^{\frac{m^2m'^2-1}{8}} = (-1)^{\frac{m^2-1}{8}} \times (-1)^{\frac{m'^2-1}{8}}.$$

The genus Γ, in which $f \times f'$ is contained, is said to be compounded of the genera γ and γ', in which f and f' are contained; and this composition is expressed by the symbolic equation $\Gamma = \gamma \times \gamma'$. It will be seen that the composition of any genus with itself gives the principal genus.

The same considerations may be extended to improperly primitive classes. Thus, if f and f' be respectively properly and improperly primitive, m and m' uneven numbers prime to one another and to D, represented by f and $\frac{1}{2}f'$, the genus of the improperly primitive class, $f \times f'$, may be inferred from the number mm', *i.e.* it is obtained by the composition of the generic characters of f and f'. Or, again, if f and f' be both improperly primitive, so that the class compounded of them is the double of an improperly primitive class, the generic character of this improperly primitive class is obtained by compounding those of the two given classes.

It follows, from these principles, that the number of classes in any two genera [of the same order] is the same. For if $\Phi_1, \Phi_2, \ldots \Phi_n$ be all the classes of any genus of properly or improperly primitive forms, F_1 a class belonging to any other genus of the same order, and ϕ a properly primitive class satisfying the equation $\Phi_1 \times \phi = F_1$, the classes $\Phi_1 \times \phi, \ldots . \Phi_n \times \phi$ are all different, and all belong to the genus (F); consequently (F) has at least as many classes as (Φ), and *vice versâ* (Φ) has at least as many as (F), *i. e.* they both contain the same number of classes.

115. *Determination of the Number of Ambiguous Classes, and Demonstration of the Law of Quadratic Reciprocity.*—The number of actually existing genera of properly primitive forms cannot exceed the number of properly primitive ambiguous classes. For let n be the number of classes in each genus, k the number of actually existing genera, so that kn is the number of properly primitive classes; let also $1, A_1, A_2, \ldots A_{k-1}$ be the properly primitive ambiguous classes. Every class produces, by its duplication, a class of the principal genus; and if K be a class of the principal genus

produced by the duplication of X, K is also produced by the duplication of $X \times A_1$, $X \times A_2$, . . $X \times A_{k-1}$, but by the duplication of no other class. If, therefore, there be n' classes in the principal genus which can be produced by duplication, the whole number of properly primitive classes is $h \times n'$, *i. e.* $hn' = kn$. But $n' \leqq n$, therefore $k \leqq h$.

It may be inferred from Art. 112, vii., that all genera which contain any ambiguous classes contain an equal number of them. We shall immediately see that the number of ambiguous classes is equal to the number of genera, and is consequently a power of 2. The number of ambiguous classes in any genus is, therefore, either zero or a power of 2; and if any genus contain 2^κ ambiguous classes, such classes will exist only in $\frac{k}{2^\kappa}$ genera.

Gauss determines the number h of properly primitive ambiguous classes by very elementary reasoning. He first finds the number of properly primitive ambiguous forms of one or other of the two types (A, 0, C) and (2B, B, C), and then assigns the number of non-equivalent classes in which these forms are contained. Let D be divisible by μ different primes; and let us except the case $D = -1$. Resolving D in every possible manner into two positive or negative factors, having no common divisor but unity, we find $2^{\mu+1}$ properly primitive forms of the type (A, 0, C); but we shall diminish this number by one-half by rejecting one of the two equivalent forms (A, 0, C) and (C, 0, A), viz. that in which $[A] > [C]$. There are no properly primitive forms of the type (2B, B, C) unless $D \equiv 3$, mod. 4, or $D \equiv 0$, mod. 8; for one or other of these congruences is implied by the equation $D = B\,(B - 2C)$, because C is uneven. Resolving D into any two factors relatively prime, if $D \equiv 3$, mod. 4, and having 2 for their greatest common divisor, if $D \equiv 0$, mod. 8, we take one of them for B, the other for $B - 2C$; and we obtain, in either case, $2^{\mu+1}$ properly primitive forms of the type (2B, B, C). If $BB' = -D$, it is easily seen that the forms (2B, B, C) and (2B′, B′, C′)* are equivalent. We may thus diminish by one-half the number of forms of the type (2B, B, C), rejecting those in which $[B] > \sqrt{[D]}$. We conclude, therefore, that if we now denote by μ the number of *uneven* primes dividing D, we have in all $2^{\mu+2}$ ambiguous forms when $D \equiv 0$, mod. 8, 2^μ when $D \equiv 1$, or $\equiv 5$, mod. 8, and $2^{\mu+1}$ in every other case. These ambiguous forms we shall call Ω, and we observe that their number is equal to the whole number of assignable generic characters (Art. 98).

To find the number of non-equivalent classes in which these forms are contained, we consider separately the case of a positive and of a negative determinant. For a negative determinant, we diminish by one-half the number of the forms by rejecting the negative forms. The remaining forms, if of the type (A, 0, C), are evidently reduced, because $A < C$; if of the type (2B, B, C), they are also reduced, unless $2B > C$, an inequality which implies that $(C, C - B, C)$, to which (2B, B, C) is equivalent, is reduced (Art. 92). The number of [positive] ambiguous classes is, therefore, one-half the number of the ambiguous forms Ω.

For a positive determinant, we deduce from the forms Ω an equal number of reduced ambiguous forms. Thus (A, 0, C) is equivalent to (A, kA, C′); and because $[A] < \sqrt{D}$, this form is reduced, if kA be positive and be the greatest multiple of [A] not surpassing $\sqrt{D}$. Similarly $(2B, (2k+1)B, C')$ is equivalent to $(2B, B, C)$, and is reduced if $(2k+1)B$ be positive, and be the greatest uneven multiple of [B] not surpassing $\sqrt{D}$. There are, therefore, as many reduced ambiguous forms as there are forms in Ω; and there are no more, because it is readily seen that every reduced ambiguous form is included in one or other of the two series of forms (A, kA, C') and $(2B, (2k+1)B, C')$ which we have obtained. But every ambiguous class contains two reduced ambiguous forms (Art. 94); we infer, therefore, that for positive as well as for negative determinants the number of ambiguous classes is one-half the number of the forms Ω, *i.e.* one-half of the number of assignable generic characters.

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* When the first two coefficients of a form are given, the third is given also; thus C′ is here used for $\frac{B'^2 - D}{2B'}$. Similar abbreviations will be employed occasionally in the sequel. The symbols [A] &c. are used, as in Art. 92, to denote the absolute values of the quantities enclosed within the brackets.

Combining this result with the theorem at the commencement of this article, we obtain a proof of the impossibility of at least one-half of the assignable generic characters. As this proof is independent of the law of quadratic reciprocity, we may employ the result to demonstrate that law. [Gauss's second demonstration, Disq. Arith., art. 262.] Let p and q be two primes, and first let one of them, as p, be of the form $4n+1$. If $\left(\frac{q}{p}\right) = -1$, we infer that $\left(\frac{p}{q}\right) = -1$; for if $\left(\frac{p}{q}\right) = +1$, we should have $\omega^2 \equiv p$, mod. q, and consequently there would exist a form $\left(q, \omega, \frac{\omega^2 - p}{q}\right)$ of det. p, of which the character would be $\left(\frac{f}{p}\right) = -1$, *i.e.* there would be 2 genera of forms of determinant p. Similarly, if $\left(\frac{q}{p}\right) = +1$, we have $\omega^2 \equiv \pm q$, mod. p; and $\left(p, \omega, \frac{\omega^2 \mp q}{p}\right)$ is a form of det. $\pm q$. If $\pm q$ be of the form $4n+1$, there will be but one genus of forms, *i.e.* the principal genus; whence $\left(\frac{p}{q}\right) = +1$. These two conclusions are sufficient to establish the theorem of reciprocity when one of the two primes is of the form $4n+1$. If both p and q be of the form $4n+3$, there are four assignable characters for the determinant pq. Of these $\left(\frac{f}{p}\right) = 1, \left(\frac{f}{q}\right) = 1$; $\left(\frac{f}{p}\right) = -1, \left(\frac{f}{q}\right) = -1$; are possible, as is shown by the existence of the forms $(1, 0, -pq)$, $(-1, 0, pq)$; the other two are therefore impossible. Hence in the form $(p, 0, -q)$ we must have either $\left(\frac{p}{q}\right) = 1 = \left(\frac{-q}{p}\right)$, or $\left(\frac{p}{q}\right) = -1 = \left(\frac{-q}{p}\right)$, which expresses the theorem of reciprocity for this case. The supplementary theorems relating to 2 and -1 can be similarly proved.

116. *Equality of the Number of Genera and of Ambiguous Classes.*—In the preceding article it has only been shown that k cannot exceed h. But, as we have already seen (Art. 102) that the number of actually existing genera is one-half the whole number of assignable generic characters, we know that $k = h$. To prove this, by the principles of the composition of forms, it is sufficient to show that $n = n'$, *i. e.* that the problem "to find a class which by its duplication shall produce a given class of the principal genus" is always resoluble. This problem Gauss actually solves (Disq. Arith., art. 286, 287); he shows, first, that any proposed binary form, belonging to the principal genus of its own determinant, can be

represented by the ternary quadratic form X^2-2YZ; and, secondly, that from this representation we can always deduce a binary form, which shall produce by its duplication the proposed form. This solution implies a previous investigation of the theory of ternary quadratic forms, and cannot be properly introduced here.

A more elementary method, however, has been given by M. Arndt (Crelle, lvi. p. 72). Let $D=\Delta S^2$, S^2 representing any square dividing D; M. Arndt observes that the ratio of the number of actually existing genera to the whole number of assignable generic characters is the same for each of the two determinants D and Δ. To prove this we make use of the following subsidiary proposition:—

"If $f=(a, b, c)$ be a properly primitive form of any det. D, and if 8M and θ be two numbers relatively prime, the necessary and sufficient condition for the resolubility of the congruence

$$ax^2+2bxy+cy^2\equiv\theta, \text{ mod } 8M \quad . \quad . \quad . \quad . \quad . \quad . \quad (A)$$

is that the supplementary characters of f (if any), and the particular characters of f (if any) which relate to uneven primes dividing both M and D, should coincide with the corresponding characters of θ."

We may add (though this is not necessary for our present purpose), that if θ_1 and θ_2 be two values of θ for each of which the congruence (A) is resoluble, it is resoluble for each an equal number of times.

On reference to the Table in Art. 98, it will be seen that the particular characters proper to the determinant Δ are included among the particular characters proper to D. Let then (Γ) and (Γ, Γ′) represent any two complete generic characters for the determinants Δ and D, the particular characters common to the two complete characters having the same values attributed to them in each. It may then be shown that the genus (Γ, Γ′) is or is not an existent genus, according as (Γ) is or is not existent. For (1) if (Γ, Γ′) be actually existent, let θ be a number prime to 2D and capable of primitive representation by some class of that genus; the congruence $\omega^2\equiv D$, mod. θ is therefore resoluble; *i.e.* the congruence $\omega^2\equiv\Delta$, mod. θ, is resoluble, so that θ can be represented by a class of properly primitive forms of det. Δ, or the genus (Γ) is actually existent. And (2) if (Γ) be an existing genus, let f be a form contained in (Γ), and θ a number prime to 2D and satisfying the generic character (Γ, Γ′). It appears from the subsidiary proposition that some number e of the linear form $8mD+\theta$ is capable of representation by f; if δ be the greatest common divisor of the indeterminates in the representation of e by f, the congruence $\omega^2\equiv\Delta$ and consequently the congruence $\omega^2\equiv D$, is resoluble for the modulus $\frac{e}{\delta^2}$, *i.e.* $\frac{e}{\delta^2}$ the character of which coincides with the character of θ, and therefore with that of the genus (Γ, Γ′), is capable of representation by a form of det. D, or (Γ, Γ′) is an actually existing genus.

If then, μ be the number of particular characters contained in (Γ, Γ′) and not in (Γ), the numbers of actually existing genera and assignable generic characters for the det. D are each 2^{μ} times the corresponding numbers for the det. Δ.

It appears from this result that it will be sufficient for our present purpose to consider determinants not divisible by any square. If (a, b, c) be a form of the principal genus of such a determinant (we suppose that a is prime to 2D), the equation $ax^2+2bxy+cy^2=\omega^2$ is resoluble with values of ω prime to

D; for if $a=a'\delta^2$, δ^2 representing the greatest square divisor of a, the equation

$$\xi^2-D\eta^2=a'\zeta^2$$

is certainly resoluble in relatively prime integers, by virtue of a celebrated theorem of Legendre*; and the values of ζ which satisfy it are prime to D; whence, if $x=\mu\frac{\xi-b\eta}{a}$, $y=\mu\eta$, $\omega=\mu\frac{\zeta}{\delta}$, μ denoting a multiplier, which renders the values of x, y, and ω integral and relatively prime, the equation $ax^2+2bxy+cy^2=\omega^2$ will be satisfied, and the values of ω will be prime to D. The form (a, b, c) is therefore equivalent to a form of the type (ω^2, λ, ν); and this form is produced by the duplication of $(\omega, \lambda, \nu\omega)$ if ω be uneven, and of $(2\omega, \lambda+\omega, \nu')$ if ω be even.

117. *Arrangement of the Classes of the principal Genus.*—If C be a class of the principal genus, the classes C, C^2, C^3, . . . will all belong to that genus. And it will be found, by reasoning similar to that employed in Euler's second proof of Fermat's theorem (see Art. 10 of this Report), (1) that the classes 1, C, C^2, . . . are all different until we arrive at a class C^μ, equivalent to the principal class; (2) that μ is either equal to, or a divisor of, the number n of classes in the principal genus; (3) that if $C^r=1$, r is a multiple of μ. The μ classes C, C^2, C^3, . . . $C^{\mu-1}$, 1, are called the period † of the class C; C is said to appertain to the exponent μ; and the determinant is *regular* or *irregular* according as classes do or do not exist which appertain to the exponent n. With the former case we may compare the theory of the residues of powers for a prime modulus; with the latter the same theory for a modulus composed of different primes (see Art. 77).

(i.) When the determinant is regular, we may take any class appertaining to the exponent n as a basis, and may represent all the classes of the principal genus (to which we at present confine ourselves) as its powers. It will then appear (1) that if d be a divisor of n, the number of classes appertaining to the exponent d is $\psi(d)$; so that, for example, the number of classes that may be taken for a base is $\psi(n)$: (2) that if $ef=n$, the equation $X^e=1$ will be satisfied by e classes of the principal genus; and if these classes be represented by A_1, A_2, . . . A_e, each of the equations $X^f=A$ will be satisfied by f different classes of the same genus: (3) that the only classes of the principal genus which satisfy the equation $X^k=1$ are those which satisfy the equation $X^d=1$, where d is the greatest common divisor of k and n.

It will be seen in particular that the equation $X^2=1$ admits of only one, or only two solutions, according as n is uneven or even; *i. e.* the principal genus of a regular determinant cannot contain more than two ambiguous classes.

To obtain a class appertaining to the exponent n, Gauss employs the same method which serves to find a primitive root of a prime number (Art. 13; Disq. Arith., art. 73, 74), and which reposes on the observation, that if A and B be two classes appertaining to the exponents α and β, neither of which divides the other, and if M, the least common multiple of α and β, be resolved into two factors p and q, relatively prime and such that p divides α and q divides β, the class $A^{\frac{\alpha}{p}}\times B^{\frac{\beta}{q}}$ will appertain to the exponent M.

(ii.) When the determinant is irregular, the classes of the principal genus cannot be represented by the simple formula C^i, and we must employ an expression of the form $C_1^{i_1} \times C_2^{i_2} \times C_3^{i_3} \ldots$ To obtain an expression thus representing all the classes of the principal genus, we take for C_1 a class appertaining to the greatest exponent θ_1 to which any class can appertain; and in general for C_μ we take a class appertaining to the greatest exponent θ_μ to which any class can appertain when its period contains no class, except the principal class, capable of representation by the formula $C_1^{i_1} \times C_2^{i_2} \times \ldots C_{\mu-1}^{i_{\mu-1}}$. The number $\frac{n}{\theta_1} = \theta_2 \times \theta_3 \times \ldots$ is called by Gauss the exponent of irregularity; and similarly we might term $\frac{n}{\theta_1\,\theta_2}$, $\frac{n}{\theta_1\,\theta_2\,\theta_3}$, &c., the second, third, &c., exponents of irregularity. From the mode in which the formula $C_1^{i_1} \times C_2^{i_2} \times \ldots$ is obtained, it can be inferred that θ_1 is divisible by θ_2, θ_2 by θ_3, and so on; whence it appears that a determinant cannot be irregular unless n be a divisible by a square; nor can it have r indices of irregularity unless n be divisible by a power of order $r+1$. Moreover, whenever the principal genus contains but one ambiguous class, the determinant is either regular or has an uneven exponent of irregularity; if, on the contrary, the principal genus contain more than two ambiguous classes, the determinant is certainly irregular, and the index of irregularity even; if it contain 2^κ ambiguous classes, the irregularity is at least of order κ, and the κ exponents of irregularity are all even.

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* Théorie des Nombres, ed. 3, vol. i. p. 41; Disq. Arith., art. 294.

† These periods of non-equivalent classes are not to be confounded with the periods of equivalent reduced forms of Art. 93.

A few further observations are added by Gauss. Irregularity is of much less frequent occurrence for positive than for negative determinants; nor had Gauss found any instance of a positive determinant having an uneven index of irregularity (though it can hardly be doubted that such determinants exist). The negative determinants included in the formulæ, $-D = 216k + 27$, $= 1000k + 75$, $= 1000k + 675$, except -27 and -75, are irregular, and have an index of irregularity divisible by 3. In the first thousand there are five negative determinants (576, 580, 820, 884, 900) which have 2 for their exponent of irregularity, and eight (243, 307, 339, 459, 675, 755, 891, 974) which have 3 for that exponent; the numbers of determinants having these exponents of irregularity are 13 and 15 for the second thousand, 31 and 32 for the tenth. Up to 10,000 there are, possibly, no determinants having any other exponents of irregularity; but it would seem that beyond that limit the exponent of irregularity may have any value.

118. *Arrangement of the other Genera.*—In the preceding article we have attended to the classes of the principal genus only; to obtain a natural arrangement of all the properly primitive classes, we observe that, if the number of genera be 2^μ, the terms of the product $(1+\Gamma_1)(1+\Gamma_2)(1+\Gamma_3)\ldots(1+\Gamma_\mu)$, in which Γ_i represents any genus not already included in the product of the $i-1$ factors preceding $1+\Gamma_i$, will represent all the genera. If, then, $A_1, A_2, \ldots A_\mu$ represent any classes of the genera $\Gamma_1, \Gamma_2, \ldots \Gamma_\mu$ respectively, and $|C|$ be the formula representing all the classes of the principal genus, the expression $|K| = |C| \times (1+A_1)(1+A_2)\ldots(1+A_\mu)$ supplies a type for a simple arrangement of all the classes of the given determinant. When every genus contains an ambiguous class, it is natural to take for $A_1, A_2, \ldots A_\mu$, the ambiguous classes contained in the genera $\Gamma_1, \Gamma_2, \ldots \Gamma_\mu$ respectively. When the principal genus contains two ambiguous classes (and when, consequently, one-half of the genera contain no such classes), let C_1 be the class taken as base (or, if the determinant be irregular, as first of the bases) in the arrange-

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ment of the classes of the principal genus, and let $\Omega_1{}^2=C_1$; it may then be shown that Ω_1 will belong to a genus containing no ambiguous class, and that the formula $|K|=|C|\times(1+\Omega_1)(1+A_2)\ldots(1+A_\mu)$, in which $A_2, \ldots A_\mu$, are ambiguous classes, represents all the classes *. In general, if the principal genus contain 2^κ ambiguous classes (a supposition which implies that the determinant is irregular, having κ even exponents of irregularity, and that there are only $2^{\mu-\kappa}$ genera containing ambiguous classes)—let $\Omega_1{}^2=C_1$; $\Omega_2{}^2=C_2$; $\ldots \Omega_\kappa{}^2=C_\kappa$—it will be found that all the classes are represented by the formula $|K|=|C|\times(1+\Omega_1)(1+\Omega_2)\ldots(1+\Omega_\kappa)(1+A_{\kappa+1})\ldots(1+A_\mu)$, in which $A_{\kappa+1}, \ldots A_\mu$ are ambiguous classes, and $\Omega_1, \Omega_1 \ldots \Omega_\kappa$ classes belonging to genera containing no ambiguous class †.

A similar arrangement of the improperly primitive classes (when such classes exist) is easily obtained. Let Σ denote the principal class of improperly primitive forms, *i. e.* the class containing the form $\left(2, 1, -\frac{D-1}{2}\right)$; we have seen (Art. 113) that the number of properly primitive classes which, compounded with Σ, produce Σ, is either one or three. When there is only one such class, the number of improperly primitive classes is equal to that of properly primitive classes; and if $|K|$ be the general formula representing the properly primitive classes, the improperly primitive classes will be represented by $\Sigma\times|K|$. When there are three properly primitive classes, which, compounded with Σ, produce Σ, the principal class will be one of them, and if ϕ be another of them, ϕ^2 will be the third; also ϕ and ϕ^2 will belong to the principal genus, and will appertain to the exponent 3. When the determinant is regular, instead of the complete period of classes of the principal genus, $1, C, C^2, \ldots C^{n-1}$, we take the same series as far as the class $C^{\frac{1}{3}n}$ exclusively; when the determinant is irregular, we can always choose the bases $C_1, C_2, \ldots$ in such a manner that the period of one of them shall contain ϕ and ϕ^2, and this period we similarly reduce to its third part by stopping just before we come to ϕ or ϕ^2. Employing these truncated periods, instead of the complete ones, in the general expression for the properly primitive classes, we obtain an expression, which we shall call $|K'|$, representing a third part of the properly primitive classes, and such that $\Sigma\times|K'|$ represents all the improperly primitive classes.

119. *Tabulation of Quadratic Forms.*—In Crelle's Journal, vol. lx. p. 357, Mr. Cayley has tabulated the classes of properly and improperly primitive forms for every positive and negative determinant (except positive squares) up to 100. The classes are represented by the simplest forms contained in them ‡; the generic character of each class, and, for positive determinants, the period of reduced forms (Art. 93) contained in it, are also given. The

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* Gauss employs a class Ω_1 producing C_1 by its duplication, both when one and when two ambiguous classes are contained in the principal genus. The number of classes requisite for the construction of the complete system of classes is therefore μ in either case, since C_1 may be replaced by $\Omega^2{}_1$.

† The principles employed by Gauss for the arrangement of the classes of a regular determinant are extended in the text to irregular determinants. If the determinant have κ' *uneven* exponents of irregularity, the number of classes requisite for the construction of the complete system of classes is $\mu+\kappa'$.

‡ The simplest form contained in a class is that form which has the least first coefficient of all forms contained in the class, and the least second coefficient of all forms contained in the class and having the least first coefficient. If a choice presents itself between two numbers differing only in sign, the positive number is preferred. In the case of an ambiguous class of a positive determinant, the simplest ambiguous form contained in the class is taken as its representative.

arrangement of the genera and classes is in accordance with the construction of Gauss, explained in the preceding articles; and the position of each class in the arrangement is indicated by placing opposite to it, in a separate column, the term to which it corresponds in the symbolic formula (such as $|K|$ or $\Sigma \times |K|$) which forms the type of the arrangement. To the two Tables of positive and negative determinants Mr. Cayley has added a third, containing the thirteen irregular negative determinants of the first thousand.

In a letter addressed to Schumacher, and dated May 17, 1841, Gauss expresses a decided opinion of the uselessness of an extended tabulation of quadratic forms. "If, without having seen M. Clausen's Table, I have formed a right conjecture as to its object, I shall not be able to express an opinion in favour of its being printed. If it is a canon of the classification of binary forms for some thousand determinants, that is to say, if it is a Table of the reduced forms contained in every class, I should not attach any importance to its publication. You will see, on reference to the Disq. Arith. p. 521 (note), that in the year 1800 I had made this computation for more than four thousand determinants" [viz. for the first three and tenth thousands, for many hundreds here and there, and for many single determinants besides, chosen for special reasons]; "I have since extended it to many others; but I have never thought it was of any use to preserve these developments, and I have only kept the final result for each determinant. For example, for the determinant −11,921, I have not preserved the whole system, which would certainly fill several pages *, but only the statement that there are 8 genera, each containing 21 classes. Thus, all that I have kept is the simple statement viii. 21, which in my own papers is expressed even more briefly. I think it quite superfluous to preserve the system itself, and much more so to print it, because (1) any one, after a little practice, can easily, without much expenditure of time, compute for himself a Table of any particular determinant, if he should happen to want it, especially when he has a means of verification in such a statement as viii. 21; (2) because the work has a certain charm of its own, so that it is a real pleasure to spend a quarter of an hour in doing it for one's self; and the more so, because (3) it is very seldom that there is any occasion to do it. . . . . . My own abbreviated Table of the number of genera and classes I have never published, principally because it does not proceed uninterruptedly." † Probably the third of Gauss's three reasons will commend itself most to mathematicians who do not possess his extraordinary powers of computation. An abbreviated Table of the kind he describes, extending from −10,000 to +10,000, would occupy only a very limited space, and might be computed from Dirichlet's formulæ for the number of classes (see Art. 104), without constructing systems of representative forms. But it would, perhaps, be desirable (nor would it increase the bulk of the Table to any enormous extent) to give for each determinant not only the number of genera, and of classes in each genus, but also the elements necessary for the construction, by composition only, of a complete system of all the classes. For this purpose it would not be necessary to specify (by means of representative forms) more than 5 or 6 classes, in the case of any determinant within the limits mentioned.

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* Mr. Cayley's Table of the first hundred negative determinants occupies about four pages of Crelle's Journal; the determinant −11,921 would occupy about one page.

† Briefwechsel zwischen C. F. Gauss und H. C. Schumacher, vol. iv. p. 30.

Report on Observations of Luminous Meteors (*ante*, pp. 1–81).

APPENDIX I.—*Errata*.

(1) p. 35, December 8, Dundee. *Column* Appearance, &c. *For* A spear-head-like crescent moon, &c. *read* A spearhead; like crescent moon, &c.

(2) p. 41, December 24, London. *Column* Direction, &c. *Insert the words* Radiant point Aldebaran.

(3) p. 43, December 27, 8^h 57^m P.M. *Column* Appearance, &c. *For* Track ending, &c. *read* Track enduring, &c.

(4) p. 57, April 29, 11^h 55^m P.M. *Column* Appearance, &c. *Read thus*—Left no track. Brilliance vanished suddenly at *b* Lacertæ. Remaining 12° of the course light red (Mars at maximum robbed of his rays), very intermittent and vacillating, died out, 2·3 seconds.

(5) p. 64, August 12, 11^h 9^m P.M. *Column* Position, &c. *Omit the words* short of the second.

(6) From five accounts of the meteor 1862, September 19, the following is a calculation of its path:—

At *London*, after explosion overhead, the meteor proceeded a considerable distance towards 69° W. of N.

At *Nottingham* the meteor passed sixty-three miles over London, seeking an earth-point 42° W. from S.

At *Hay* (*South Wales*) the meteor passed fifty-seven miles over London, seeking an earth-point 70° E. from S.

At *Torquay* the meteor passed $57\frac{3}{4}$ miles over London, seeking an earth-point 9° E. from N.

At *Hawkhurst* the meteor passed forty-seven miles over London, seeking an earth-point 66° W. from N.

An earth-point seven miles S.W. from Hereford satisfies the observations in the following manner:—

London,	70° W. from N.	(observed 69° W. from N.).
Nottingham,	46° W. from S.	(observed 42° W. from S.).
Hay,	70° E. from S.	(observed 70° E. from S.).
Torquay,	14° E. from N.	(observed 9° E. from N.).
Hawkhurst,	62° W. from N.	(observed 66° W. from N.).

The errors of observation being in no case greater than 5°, from the calculated bearings. A ground-point so close to Hay sufficiently explains anomalies in the observation at that place; but its distance is on the other hand 120 miles from London, where the meteor appears to have been fifty-six miles above the earth. The path of the meteor was therefore inclined downwards, from 25° above the horizon towards 70° W. of N. A visible flight of 115 miles, from eighty-three miles over Canterbury to thirty-three miles over Oxford, performed in three to four seconds of time, is the result obtained from the comparison of these observations.

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709	2	32	2	0	92·5	20	100	406·9	10	0	12	0	2	0	7	6	5	4	92·5	10·949	1·739	15·88
[illegible]	2	30½	3	0	36	14	100	249·4	9	0	11	6	1	10	6	3	8	9	83·613	9·485	1·085	11·44
[illegible]	2	[illegible]	4	0	57·4	20	[illegible]	3352·0	19	1	29	3¾	3	11⅝	12	8	10	2	57·4	16·573	4·004	24·16
3930	2	66	3	6	63·83	20	500	2282·6	18	0	19	0	3	6	12	1	11	6	63·83	11·963	1·385	11·58
718	2	45	2	0	85	20	200	731·6	11	0	16	6	2	5¼	7	1	4	8	85	[illegible]	[illegible]	[illegible]
3602	2	76⅛	3	6	51	20	600	2079·8	18	2	26	0	3	1	12	2	8	9	51	13·078	1·252	9·57
3614	2	76⅛	3	6	51	20	600	2219·2	18	2	26	0	3	1	12	2	8	10	51	13·078	1·365	10·44
3602	2	76⅛	3	6	42·4	20	600	1251·0	18	2	26	0	3	1	12	2	9	0	42·4	10·874	0·942	8·66
5106	2	76⅛	3	6	56·75	20	600	2423·8	18	2	26	2	3	1	12	2	12	10	56·75	14·648	3·774	25·76
5106	2	76⅛	3	6	45·75	20	600	1273·8	18	2	26	2	3	1	12	2	12	10	45·75	11·809	2·737	23·18
5083	2	92	4	0	60	20	1000	4293·2	20	0	25	8⅜	2	10	13	6	10	5	60	15·209	2·066	13·59
803·5	2	45	2	0	84	20	200	629·9	11	0	16	5¼	2	7⅞	7	1	4	7	84	13·257	3·494	26·36
803·5	2	45	2	0	63·75	20	200	308·7	11	0	16	5¼	2	7⅞	7	1	4	7	63·75	10·061	1·614	16·04
550	2	40½	2	0	66	20	160	267·3	11	0	15	0	2	7	7	1	4	7	66	9·765	0·965	9·88
2520	2	64	3	0	48·375	10	400	857·3	17	1	22	10½	3	0	9	2	10	8	48·375	10·915	1·404	12·86
645	2	45	2	0	76·66	20	200	503·8	11	0	16	6½	2	8	7	1	3	6	76·66	12·510	3·165	25·30
645	2	45	2	0	88·5	20	200	627·8	11	0	16	6½	2	8	7	1	3	6	88·5	14·440	4·182	28·96
970	2	34	2	9	58·58	11	100	236·2	11	0	13	6	2	0	8	0	4	9	58·58	7·801	0·825	10·58
8440	2	71	3	0	62	20	500	1889·9	18	0	20	0	3	9	12	0	10	4	62	12·231	0·902	7·37
3245	2	=64¼	3	4	68·5	20	500	2052·3	17	0	18	6	3	0	11	1	10	9	68·5	12·503	1·548	12·38
469	2	40½	2	0	76·6	20	160	551·2	11	1	15	0	2	6¼	7	1	3	9	76·6	11·334	1·233	10·88
546·5	2	40½	2	0	63·33	20	160	224·6	11	1	15	0	2	6¼	7	1	4	4	63·33	9·371	1·359	14·50
912	2	42½	2	2	112	20	200	984·8	12	0	15	0	2	9	8	3	4	3	112	16·572	5·858	35·35

Do.	868	11·536	10 July 1857	Stokes Bay	200	0	30	4	10	3	12	6	
NEPTUNE	2830	[illegible]	[illegible]	[illegible]	216	3	54	6	17	6	21	10	75
SHANNON	2651	10·492	11 Nov. 1856	Stokes Bay	235	0	50	0	20	10	22	5	781
Do.	2651	11·216	18 Nov. 1856	Stokes Bay	235	0	50	0	20	6	22	3	770
Do.	2651	11·708	2 Dec. 1856	Stokes Bay	235	0	50	0	20	10	21	11	770
Do.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	50	0	19	2	23	6	767·

TABLE 6.—RESULTS OF THE TRIALS OF H.M.'s SCREW SHIPS, OFFICIALLY TABULATED BY 1

rea. of dship ction.	Displacement.	ENGINES.								PROPELLER.													
		Cylinders.		Length of Stroke.		Number of Revolutions per minute.	Weight per square inch on the safety valve.	Horse-power.		Dimensions.						Centre above bottom of false keel.		Immersion of centre at the time of trial.		Number of revolutions per minute.	Rate in knots per hour.	Slip.	
		No.	Diameter.					Nominal.	Indicated.	Diameter.		Pitch.		Length.								In knots per hour.	Per cent.
q. Ft.	Tons.		Inches.	Ft.	In.		Lbs.	Horses.	Horses.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.		Knots.	Knots.	
740	3150	2	=58⅛	3	3	62·3	20	400	1533·3	17	0	17	6	3	0	11	4	10	2	62·3	10·754	1·204	11·20
461	2388	4	=45⅛	3	0	51·75	10	400	824·9	17	2¼	22	7⅝	2	9	9	7	8	4	51·75	11·555	1·239	10·72
012	4806	2	=70¾	3	6	60·58	20	600	1948·5	18	0	21	10	3	4	11	5	13	4	60·58	13·048	2·331	17·87
790	3013	4	55	2	6	52	10	450	930·6	16	0	18	5	3	1	10	4	12	7	52	9·447	2·617	27·70
195	605	2	45	2	0	85·5	20	200	587·2	11	0	16	0	2	6	7	1	3	5	85·5	13·494	2·843	21·07
250	718	2	32	2	0	92	20	100	387·4	10	0	12	0	2	0	7	6	5	3	92	10·890	1·283	11·78
819	3562	2	76⅛	3	6	57·66	20	600	2518·4	18	1⅓	26	1	3	0	11	9	10	10	57·66	14·835	2·644	17·82
814	3550	2	76⅛	3	6	47·75	20	600	1361·8	18	1½	26	1	3	0	11	9	10	9	47·75	12·286	1·799	14·64
856	4190	2	82	4	0	59	20	800	3582·6	19	0	27	6	4	2	13	2	7	8	59	16·005	3·023	18·89
378	1263	2	46⅛	3	0	42	10	200	447·1	9	0	7	3	1	4	8	0	7	1	126	9·011	1·211	13·44
780	4480	2	82$\frac{1}{16}$	3	8	59·166	20	800	3024·5	20	0	25	0	3	6	11	9	11	0	59·166	14·590	1·910	13·09
771	4426	2	82$\frac{1}{16}$	3	8	61·6	20	800	3350·3	20	0	25	0	3	6	11	9	10	7	61·6	15·191	2·104	13·85
195	500	2	25½	1	9	82	20	60	190·1	9	0	11	0	1	9¾	6	6	4	10	82	8·897	1·250	14·05
604	2565	2	=55	3	0	64·833	12	360	894·8	15	6	15	5⅓	2	5	10	1	10	2	64·833	9·886	0·951	9·62
440	2260	4	=45⅛	3	0	54·083	12	400	878·8	17	2¼	22	7⅞	2	9	9	7	7	8	54·083	12·075	1·412	11·
810	3940	2	82	4	0	60·333	20	800	3731·5	19	0	27	6	4	2	13	2	8	1	60·333	16·366	3·344	
754	3655	2	76	3	6	54	20	600	2471·4	19	4	25	9⅓	3	3	11	8	10	5	54	13·738	1·689	
750	3631	2	76	3	6	55	20	600	2490·1	19	4	25	9⅓	3	3	11	8	10	4	55			
466	1780	2	64	3	0	66	20	400	1798·2	16	0	24	0	3	0	10	4	6	7	66			

Ditto	Seaward and Capel	Horizontal	1038	9·913	18 Oct. ..1853	Stokes Bay	192	6¼	34	4	15	9	17	4	471	[illegible]	[illegible]	[illegible]	2 0	66
Ditto	Seaward and Capel	Horizontal	1038	9·571	2 Nov. ..1853	Stokes Bay	192	6¼	34	4	15	10	17	4	472	1722	4	46¼	2 0	66
Ditto	Seaward and Capel	Horizontal	1038	9·772	7 Nov. ..1853	Stokes Bay	192	6¼	34	4	15	9	17	4	471	1716	4	46¼	2 0	66
CONQUEROR	John Penn and Son	Horizontal, Trunk	3224	10·806	16 June ..1856	Plymouth.	240	0	55	4	24	3	26	4	1132	[illegible]	[illegible]	82	4 0	55
MIRANDA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MOHAWK	Humphrys, Tennant & Co.	Horizontal	670	9·925	7 April, 1856	Stokes Bay	150	0	28	4	10	2	11	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

PS, OFFICIALLY TABULATED BY THE ADMIRALTY IN 1856.

INES.				PROPELLER.														RATIO OF							
	nch on	e.	Horse-power.		Dimensions.						om of		re at l.		tions	our.	Slip.		readth.	meter.	to	Indicated power.		Mid. Sec. / Power.	Mid. Sec. / Power.
)·5		15	128	416	6	3½	10	0	1	8½	3	0	4	1	202·5	19·975	6·759	38·84	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
72·5		20	300	1068	14	1	17	7	2	10½	9	6	9	10	72·5	12·575	2·167	17·15	4·47	1·25	3·71	1·85	6·28	611·9	180·2

… to Stokes Bay, the wind being No. 8 to No. 9 from the eastward.

Wind No. 2.

Wind No. 1.

UNIVERSITY CALIFORNIA

741
368
105
152
150
155
414
546
821
181
438
989
989
741
207
326
392
420
400
313
278
374
343
423
313
986
316
755
316
990
926
305
300
752

	20	100	672·9	11	0⅜	14	10½	2	6¼	7	1	4	11	86·5	12·602	0·832	6·56	6·32	1·35	2·24	3·13	9·46	533·0	176·4	
	10	350	836·8	14	5¼	16	3	2	8¼	9	2	10	3	66	10·579	1·643	15·53	5·31	1·13	3·33	1·54	4·57	464·7	156·0	Vessel not in good trim. Weather squally.
·25	20	200	706·8	11	0	16	0	2	6	7	1	4	4	83·25	13·139	2·406	18·31	6·35	1·45	2·43	3·06	8·60	404·1	143·8	Wind No. 4 to No. 5.
3·32	10	100	185·8	11	0	13	6	2	0	8	0	5	6	53·32	7·100	1·072	15·10	5·51	1·23	3·49	0·56	1·76	391·4	124·6	
56	10	100	203·1	11	0	13	6	2	0	8	0	6	9	56	7·457	1·101	14·76	5·51	1·23	4·10	0·52	1·70	493·1	151·4	Complete with stores for sea.
83	20	160	611·7	11	0⅜	15	0	2	6½	7	1	4	8¼	83	12·281	—	—	6·32	1·36	2·26	2·82	8·52	—	—	Vessel not in trim.

aribus, as the area of the midship section, of the cube root of the displacement.

er, more especially the last two, are abso- re not so far from the truth as to render ison, of which they are the basis, made screw vessels; while between two vessels gines and displacement, or in the area of rison is not only highly interesting, but it out the forms of vessels and proportion of ed. In some striking cases it is scarcely rison than that of speed. For example, as 1850, the *Teazer*, after her form had been may be seen in the table printed in 1850, the *Teazer*, after her form had been improved, went above a knot an hour faster with 40 horse engines than she had previously gone with engines of 100 horse power. Again, these engines of 100 horse, when transferred to the *Rifleman*—a vessel approaching to double the tonnage—drove her, after her form had been altered, as fast as she was previously driven by engines of double the power, and nearly two knots faster than the same engines drove the smaller vessel before the alteration of her after-body.

Admiralty, August, 1856.

okes Bay, April 2

r Blade per ft.

SUMMARY MADE FRO SHIPS INCLU
N IN PRECED

Date.	Name of Ship.	Speed per hour.	Slip per cent. of Wheels and Screw.
Voyage 6th	Seine	11·05	20·9
„ 10th	Tasmanian	10·78	17·27
„ 38th	Atrato	10·94	19·5
„ 9th	Shannon	10·13	22·8
„ 7th	Seine	11·06	20·0
„ 11th	Tasmanian	11·12	15·0
„ 39th	Atrato	11·47	19·3
„ 10th	Shannon	10·08	20·7
„ 8th	Seine	10·85	21·1
„ 49th	La Plata	11·11	13·3
„ 40th	Atrato	11·61	20·0
„ 11th	Shannon	10·60	20·4
„ 9th	Seine	11·41	18·3
„ 50th	La Plata	11·3	11·2
„ 41st	Atrato	11·41	18·7
„ 12th	Shannon	9·21	18·0
„ 10th	Seine	11·36	22·4
„ 51st	La Plata	10·09	10·5
„ 42nd	Atrato	11·57	20·2

Indicator Horse-power
230
230
230
270
180
220
220
270
270
90
90
90
270
60
60
60
60
60
60
120
120
120
120
120
120
85
70
70
40
60
60
250
250
316
316
316
316
230
230
250
280

4						
4·27	665	16·61	20·55	......	Return Flue......	1855
8·03	2619	11·39	14·06	676	Return Flue......	1853
8·72	2685	11·67	14·42	676	Return Flue......	1854
9·20	2816	12·84	15·12	676	Return Flue......	1854
...	3204	11·86	14·66	861$\frac{52}{64}$	Return Flue......	1856
7·12	1890	10·50	12·97	581$\frac{41}{64}$	Return Flue......	1853
...	...	......	......	......	Return Flue......	......
7·29	2077	9·44	11·66	758$\frac{62}{64}$	Return Flue......	......
7·64	1961	8·92	11·01	758$\frac{62}{64}$	Return Flue......	1851
8·51	2926	10·84	13·38	904$\frac{54}{64}$	Tubular...........	1853
9·24	3197	12·95	16·00	904$\frac{53}{64}$	Tubular...........	1852
5·61	1291	14·35	17·72	788$\frac{51}{64}$	Tubular...........	1852
6·23	1333	14·81	18·29	788$\frac{51}{64}$	Tubular...........	1853
6·12	1323	14·69	18·15	788$\frac{51}{64}$	Tubular...........	1852
9·70	3232	11·97	14·78	896	Tubular...........	1852
4·55	678	11·31	13·86	300	Tubular...........	1853
5·01	822	13·71	16·93	300	Tubular...........	1853
5·47	781	13·01	16·07	300	Tubular...........	1853
6·37	826	13·77	17·02	278$\frac{62}{64}$	Tubular...........	1853
6·04	758	12·66	15·61	278$\frac{62}{64}$	Tubular...........	1853
6·02	773	12·88	15·91	278$\frac{62}{64}$	Tubular...........	1853
7·85	1422	11·85	14·63	557	Return Flue......	......
2·20	1501	12·51	15·45	......	Tubular...........	1854
3·60	1417	11·80	14·58	......	Tubular...........	1854
3·25	1128	9·41	11·62	......	Tubular...........	1853
3·02	1304	10·86	13·42	......	Tubular...........	1853
3·67	1077	8·97	11·08	......	Tubular...........	1853
...	...	......	......	......	Tubular...........	1853
3·31	856	12·22	15·20	......	Tubular...........	1857
3·36	633	9·04	11·16	......	Tubular...........	1855
3·20	505	12·63	15·60	......	Tubular...........	1855
6·92	1439	24	29·63	687$\frac{12}{64}$	Lamb's Patent...	1854
6·91	1290	21·50	26·55	687$\frac{12}{64}$	Lamb's Patent...	1854
8·87	3585	14·14	17·46	......	Return Flue......	1856
9·47	3412	13·65	16·85	......	Return Flue......	1856
					Return Flue......	1856
...	...	......	......	......	Return Flue......	1857
					Return Flue......	1857
					Return Flue......	1857
...	...	......	......	......	Tubular...........	1856
...	...	......	......	......	Tubular...........	1856
...	...	......	......	......	Return Flue......	1856
9·47	2899	10·35	12·78	......	Tubular...........	1856

TO LIVERPOOL, MAY AND JUNE, 1862.

1	GENERAL REMARKS.

ARKS.
; 6 a.m. starboard N.E. 12 miles. by N., 9 miles from which I take
nd heavy sea.
eavy rain.
hick rainy weather.
eavy sea and hard squalls.
her.
l.
al.
terre.
ortugal.
incent.
. by W. 12 miles. it of Gibraltar; 8 a.m. abreast of
r; noon, abreast of Cape de Gatte.
r.
ther.
ht N.E., Sardinia E.N.E. 10 miles.
our of Civita Vecchia.

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

NOTICES AND ABSTRACTS

OF

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MATHEMATICS AND PHYSICS.

MATHEMATICS.

Address by G. G. Stokes, *M.A., F.R.S. &c., Lucasian Professor of Mathematics in the University of Cambridge.*

It has been customary for some years, in opening the business of the Section, for the President to say a few words respecting the object of our meetings. In this Section, more perhaps than in any other, we have frequently to deal with subjects of a very abstract character, which in many cases can be mastered only by patient study, at leisure, of what has been written. The question may not unnaturally be asked—If investigations of this kind can best be followed by quiet study in one's own room, what is the use of bringing them forward in a sectional meeting at all? I believe that good may be done by public mention, in a meeting like the present, of even somewhat abstract investigations; but whether good is thus done, or the audience are merely wearied to no purpose, depends upon the judiciousness of the person by whom the investigation is brought forward. It must be remembered that minute details cannot be followed in an exposition *vivâ voce*; they must be studied at leisure; and the aim of an author should be to present the broad leading ideas of his research, and the principal conclusions at which he has arrived, clearly and briefly before the Section. It is then possible to discuss the subject-matter; to offer suggestions of new lines of experiment, or new combinations of ideas; and such discussions and suggestions, it seems to me, are among the most important business of a meeting such as this. Any one who has worked in concert with another zealously engaged in the same research must have felt the benefit arising from the mutual interchange of ideas between two different minds. Suggestions struck out by one call up new trains of thought and fructify in the mind of another; whereas they might have remained barren and unfruitful in the mind of the original suggester. The benefit of cooperation is by no means confined to the carrying out, according to a preconcerted plan, of a research involving labour rather than invention; it is felt in a most delightful form in the prosecution of original investigations. In a meeting like the present, we have the benefit of the mutual suggestions, not of two, but of many persons, whose minds are directed to the same object. The number of papers already in the hands of your Secretaries shows that there will be no lack of matter in this Section: the difficulty will rather, I apprehend, be to get through the business before us in the time prescribed. On this account the Section will, I hope, bear with me if I should sometimes feel myself compelled, in justice to the authors of papers which are placed later on our lists, to cut short discussions which otherwise might have been further prolonged with some interest.

On Capillary Attraction. *By the* Rev. F. Bashforth, *B.D.*

The theories of capillary action brought forward by Laplace, Young, and Poisson lead to the same form of differential equation to the free surface of a drop of fluid. During the last fifty years many attempts have been made to compare theory and experiment, but the results arrived at seem to be quite unsatisfactory. The experiments have generally been made by measuring the heights to which fluids rose in capillary tubes. The smaller the diameter of the tube, the greater is the elevation or depression of a fluid; but at the same time it becomes more difficult to secure a bore of a perfectly circular section and a surface perfectly clean. Laplace attempted to test his theory by comparing the measured thickness of large drops of mercury with their theoretical thickness obtained by an *approximate* solution of his differential equation.

After duly considering all the circumstances of the case, it appeared to the author that the forms assumed by drops of fluid, of small or moderate size, afforded the best means for testing the theory of capillary action. The drops of fluid may rest on horizontal planes which they do not wet, or they may hang below horizontal surfaces which they do wet. Extensive tables have been calculated, which give the exact theoretical forms of all drops of fluid resting upon horizontal planes, as mercury on glass, within the limits of size to which it seems desirable to restrict experiments.

In order to determine the exact forms of drops of fluid, a microscope has been mounted so that it can be moved horizontally or vertically by micrometer screws provided with divided heads. In the focus of the eyepiece are two parallel horizontal and two parallel vertical lines, forming by their intersections a small square in the centre. The lines are purposely made rather thick in order that they may be seen without difficulty, and before reading off the screw-head divisions, care is taken to cause the image of the outline of the drop to pass through the middle point of the square caused by the intersection of the cross lines. Thus the coordinates are obtained of as many points as may be thought necessary, and afterwards the form of a section of the drop, passing through the axis of its figure, may be drawn by a scale of equal parts. By trial, a theoretical form must be fitted to this experimental form, using the tables. When this is satisfactorily accomplished, the value of Laplace's a is known, as well as the value of b, the radius of curvature at the vertex: a determines the theoretical *form* of the drop, and b its *size*.

Only one or two satisfactory measurements have been made at present, but sufficient has been done to show that such values may be assigned to the constants as to secure a most exact agreement of the theoretical with the experimental form of the free surface of a drop of fluid resting on a horizontal plane. It remains to be seen whether a is constant for drops of all sizes of the same fluid at the same temperature. If experiment be found to agree with theory, then the effect of a variation of temperature upon a must be determined.

This method of proceeding affords the means of determining with great accuracy the angle of contact, because the tables calculated from theory give the coordinates for points, where the inclination of the tangent to the horizon is known, at intervals of one degree, and parts of a degree can be calculated for by proportional parts.

If the experiments on mercury appear to confirm theory, it will be desirable to complete the tables for the forms of pendent drops of fluid, because it will be very difficult, if not impossible, to find supporting planes which such fluids as oils, water, spirit of wine, &c. do not wet or adhere to. In such case it appears to be possible to make use of pendent drops alone for the determination of a. When a has been determined for each of two fluids, as spirit of wine and oil, it will be desirable to examine the mutual action at their common surfaces, which may be done by measuring the forms of drops of one fluid immersed in a bath of the other fluid contained in a cell having parallel and transparent vertical sides and horizontal planes at the top and bottom.

Since the differential equations of Laplace and Poisson are the same in form, it is evident that the above measurements for a single fluid cannot decide the difference between them. It seems, however, manifest that the constitution of the surface is very different from the interior of a fluid. But the thickness of this surface of supposed variable density is so small as to be insensible. Since there is a certain elastic force of vapour in contact with its fluid corresponding to every temperature, may we not assume that the density of this indefinitely thin envelope may vary from the density of the fluid inside to the density of the vapour outside?

On the Differential Equations of Dynamics. By Professor BOOLE, *F.R.S.*

Referring to the reduction, by Hamilton and Jacobi, of the solution of the dynamical equations to that of a single *non*-linear partial differential equation of the first order, and to that, by Jacobi, of the latter to the solution of certain systems of linear partial differential equations of the first order,—the author showed, 1st, how, from an integral of *one* equation of any such system, a common integral of all the equations of the system could, when a certain condition dependent upon the properties of symmetrical *gauche* determinants is satisfied, be deduced by the solution of a single ordinary differential equation of the first order susceptible of being made integrable by means of a factor; 2ndly, how the common integral could be found when this condition was not satisfied.

On an Instrument for describing Geometrical Curves; invented by H. JOHNSTON, *described and exhibited by the* Rev. DR. BOOTH, *F.R.S.*

This instrument supplies a want which has been felt by architects and sculptors. By its help, geometrical spirals of various orders may be described with as much manual facility as a circle may be drawn on paper by a common compass.

On a Certain Curve of the Fourth Order. By A. CAYLEY, *F.R.S.*

The curve in question is the locus of the centres of the conics which pass through three given points and touch a given line; if the equations of the sides of the triangle formed by the three points are $x=0, y=0, z=0$, these coordinates being such that $x+y+z=0$ is the equation of the line infinity, and if $\alpha x+\beta y+\gamma z=0$ be the equation of the given line, then (as is known) the equation of the curve is

$$\sqrt{\alpha x(y+z-x)}+\sqrt{\beta y(z+x-y)}+\sqrt{\gamma z(x+y-z)}=0.$$

The special object of the communication was to exhibit the form of the curve in the case where the line cuts the triangle, and to point out the correspondence of the positions of the centre upon the curve, and the point of contact on the given line.

On the Representation of a Curve in Space by means of a Cone and Monoid Surface. By A. CAYLEY, *F.R.S.*

The author gave a short account of his researches recently published in the 'Comptes Rendus.' The difficulty as to the representation of a curve in space is, that such a curve is not in general the complete intersection of two surfaces; any two surfaces passing through the curve intersect not only in the curve itself, but in a certain companion curve, which cannot be got rid of; this companion curve is in the proposed mode of representation reduced to the simplest form, viz. that of a system of lines passing through one and the same point. The two surfaces employed for the representation of a curve of the nth order are, a *cone* of the nth order having for its vertex an arbitrary point (say the point $x=0, y=0, z=0$), and a *monoid* surface with the same vertex, viz. a surface the equation whereof is of the form $Qw-P=0$, P and Q being homogeneous functions of (x, y, z) of the degrees p and $p-1$ respectively (where p is at most $=n-1$). The monoid surface contains upon it $p(p-1)$ lines given by the equations $(P=0, Q=0)$; and the cone passing through $n(p-1)$ of these lines (if, as above supposed, $p \not> n-1$, this implies that some of these lines are multiple lines of the cone), the monoid surface will besides intersect the cone in a curve of the nth order.

On the Curvature of the Margins of Leaves with reference to their Growth. By W. ESSON, *M.A.*

Leaves have a right and left margin on each side of their axis. These margins

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are of different lengths, but of the same shape. The length differs owing to circumstances of growth, such as the left margin being next the stem or next a leaflet, forming with it a composite leaf. The curvature of the margin has been ascertained in many instances to be that of the reciprocal spiral $\left(r=\frac{a}{\theta}\right)$. In some leaves the pole of curvature lies on the axis, in others in the body of the leaf, and in others entirely outside the leaf. If the leaflets of a composite leaf have this curvature, their extreme points lie on a reciprocal spiral (*e. g.* the horse-chestnut leaf). It is probable that more irregular leaves have margins which are merely modifications of the reciprocal spiral or other spirals, such as the Lituus $\left(r=\frac{a}{\sqrt{\theta}}\right)$.

The growth of a margin may be represented by increments of an arc of the spiral cut off by an increasing chord or radius vector. By this means may be accurately determined the growth of a leaf under given circumstances of soil, temperature, and moisture. It is only necessary to register the amount of angular rotation of the radius vector of the spiral.

Quaternion Proof of a Theorem of Reciprocity of Curves in Space.

By Sir William Rowan Hamilton, *LL.D. &c.*

Let ϕ and ψ be any two vector functions of a scalar variable, and $\phi', \psi', \phi'', \psi''$ their derived functions, of the first and second orders. Then each of the two systems of equations, in which c is a scalar constant,

$$(1) \; .\;.\;.\;. \; \mathrm{S}\phi\psi=c, \qquad \mathrm{S}\phi'\psi=0, \qquad \mathrm{S}\phi''\psi=0,$$

$$(2) \; .\;.\;.\;. \; \mathrm{S}\psi\phi=c, \qquad \mathrm{S}\psi'\phi=0, \qquad \mathrm{S}\psi''\phi=0,$$

or each of the two vector expressions,

$$(3) \; .\;.\;.\;. \; \psi=\frac{c\mathrm{V}\phi'\phi''}{\mathrm{S}\phi\phi'\phi''}, \qquad (4) \; .\;.\;.\;. \; \phi=\frac{c\mathrm{V}\psi'\psi''}{\mathrm{S}\psi\psi'\psi''},$$

includes the other.

If then, from any assumed origin, there be drawn lines to represent the reciprocals of the perpendiculars from that point on the osculating planes to a first curve of double curvature, those lines will terminate on a second curve, from which we can *return* to the first by a precisely similar process of construction.

And instead of thus taking the *reciprocal* of a *curve* with respect to a *sphere*, we may take it with respect to *any surface* of the *second order*, as is probably well known to geometers, although the author was lately led to perceive it for himself by the very simple *analysis* given above.

On a certain Class of Linear Differential Equations.

By the Rev. Robert Harley, *F.R.A.S.*

Theorem.—*From any algebraic equation of the degree* n, *whereof the coefficients are functions of a variable, there may be derived a linear differential equation of the order* n – 1, *which will be satisfied by any one of the roots of the given algebraic equation.* The differential equation so satisfied is called, with respect to the algebraic equation, its "differential resolvent." The connexion of this theorem, which is due to Mr. Cockle, with a certain general process for the solution of algebraic equations, led the author to consider its application to the two following trinomial forms, viz.

$$y^n-ny+(n-1)x=0, \; .\; (\mathrm{I.})$$

$$y^n-ny^{n-1}+(n-1)x=0, \; .\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\; (\mathrm{II.})$$

to either of which any equation of the nth degree, when n is not greater than 5, can, by the aid of equations of inferior degrees, be reduced. The several differential resolvents for the successive cases $n=2, 3, 4, 5$ were calculated; and by induction the general differential resolvents were formed. Following Professor Boole's symbolical process and using the ordinary factorial notation, that is to say, representing

$$(n)\,(n-1)\,(n-2)\;.\;.\;.\;(n-r+1)$$

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by $[n]^r$, the differential resolvent of (I.) was found to take the form

$$n^{n-1}\left[x\frac{d}{dx}\right]^{n-1}y-(n-1)^{n-1}\left[\frac{n}{n-1}x\frac{d}{dx}-\frac{2n-1}{n-1}\right]^{n-1}x^{n-1}y=[1]^{n-1}[n-1]^{n-1}x. \, . \, . \quad \text{(A)}$$

In like manner, the differential resolvent of (II.) was found to be

$$n^{n-1}\left[(n-1)x\frac{d}{dx}\right]^{n-1}y-(n-1)\left(nx\frac{d}{dx}-n-1\right)\left[nx\frac{d}{dx}-2\right]^{n-1}xy=[n-1]^{n-1}x. \, . \, . \, . \, . \quad \text{(B)}$$

Every differential resolvent may be regarded under two distinct aspects. It may be considered either, first, as giving in its complete integration the solution of the algebraic equation from which it has been derived; or, secondly, as itself solvable by means of that equation. In the first aspect the author has considered the differential equation (A) in a paper entitled "On the Theory of the Transcendental Solution of Algebraic Equations," just published in the 'Quarterly Journal of Pure and Applied Mathematics,' No. 20. In the second aspect every differential resolvent of an order higher than the second gives us, at least when the dexter of its defining equation vanishes, a new primary form, that is to say, a form not recognized as primary in Professor Boole's theory. And in certain cases in which the dexter does not vanish, a comparatively easy transformation will rid the equation of the dexter term, and the resulting differential equation will be of a new primary form.

On the Volumes of Pedal Surfaces. *By* T. A. Hirst, *F.R.S.*

The pedal surface being the locus of the feet of perpendiculars let fall from any point in space, the *pedal origin*, upon all the tangent planes of a given fixed primitive surface, will, of course, vary in form as well as in magnitude with the position of its origin. If, however, the volume of the pedal be considered as identical with that of the space swept by the perpendicular, as the tangent plane assumes all possible positions,—a definition which will apply to unclosed as well as to closed pedals,—the following two general theorems may be enunciated:—1. Whatever may be the nature of the primitive surface, the origins of pedals of the same volume are, in general, situated on a surface of the third order. 2. The primitive surface being closed, but in other respects perfectly arbitrary, the origins of pedals of constant volume lie on a surface of the second order; and the entire series of such surfaces constitutes a system of concentric, similar, and similarly-placed quadrics, the common centre of all being the origin of the pedal of least volume.

On the Exact Form and Motion of Waves at and near the Surface of Deep Water. *By* William John Macquorn Rankine, *C.E., LL.D., F.R.SS. L. & E. &c.*

The following is a summary of the nature and results of a mathematical investigation, the details of which have been communicated to the Royal Society.

The investigations of the Astronomer Royal and of Mr. Stokes on the question of straight-crested parallel waves in a liquid proceed by approximation, and are based on the supposition that the displacements of the particles are small compared with the length of a wave. Hence it has been legitimately inferred that the results of those investigations, when applied to waves in which the displacements are considerable as compared with the length of wave, are only approximate.

In the present paper the author proves that one of those results—viz. that in very deep water the particles move with a uniform angular velocity in vertical circles whose radii diminish in geometrical progression with increased depth, and consequently that surfaces of equal pressure, including the upper surface, are trochoidal—is an exact solution for all possible displacements, how great soever.

The trochoidal form of waves was first explicitly described by Mr. Scott Russell; but no demonstration of its exactly fulfilling the cinematical and dynamical conditions of the question has yet been published, so far as the author knows.

In 'A Manual of Applied Mechanics' (first published in 1858), the author stated that the theory of rolling waves might be deduced from that of the positions assumed by the surface of a mass of water revolving in a vertical plane about a horizontal axis; but as the theory of such waves was foreign to the subject of the book, he deferred until now the publication of the investigation on which that statement was founded.

Having communicated some of the leading principles of that investigation to Mr. William Froude in April 1862, the author was informed by that gentleman that he had arrived independently at similar results by a similar process, although he had not published them. The introduction of Proposition II. between Propositions I. and III. is due to a suggestion by Mr. Froude.

The following is a summary of the leading results demonstrated in the paper:—

Proposition I.—In a mass of gravitating liquid whose particles revolve uniformly in vertical circles, a wavy surface of trochoidal profile fulfils the conditions of uniformity of pressure,—such trochoidal profile being generated by rolling, on the under side of a horizontal straight line, a circle whose radius is equal to the height of a conical pendulum that revolves in the same period with the particles of liquid.

Proposition II.—Let another surface of uniform pressure be conceived to exist indefinitely near to the first surface: then if the first surface is a surface of continuity (that is, a surface always traversing identical particles), so also is the second surface. (Those surfaces contain between them a continuous layer of liquid.)

Corollary.—The surfaces of uniform pressure are identical with surfaces of continuity throughout the whole mass of liquid.

Proposition III.—The profile of the lower surface of the layer referred to in Proposition II. is a trochoid generated by a rolling circle of the same radius with that which generates the upper surface; and the tracing-arm of the second trochoid is shorter than that of the first trochoid by a quantity bearing the same proportion to the depth of the centre of the second rolling circle below the centre of the first rolling circle, which the tracing-arm of the first rolling circle bears to the radius of that circle.

Corollaries.—The profiles of the surfaces of uniform pressure and of continuity form an indefinite series of trochoids, described by equal rolling circles, rolling with equal speed below an indefinite series of horizontal straight lines.

The tracing-arms of those circles (each of which arms is the radius of the circular orbits of the particles contained in the trochoidal surface which it traces) diminish in geometrical progression with a uniform increase of the vertical depth at which the centre of the rolling circle is situated.

The preceding propositions agree with the existing theory, except that they are more comprehensive, being applicable to large as well as to small displacements.

The following is new as an exact proposition, although partly anticipated by the approximative researches of Mr. Stokes:—

Proposition IV.—The centres of the orbits of the particles in a given surface of equal pressure stand at a higher level than the same particles do when the liquid is still, by a height which is a third proportional to the diameter of the rolling circle and the length of the tracing-arm (or radius of the orbits of the particles), and which is equal to the height due to the velocity of revolution of the particles.

Corollaries.—The mechanical energy of a wave is half actual and half potential—half being due to motion, and half to elevation.

The crests of the waves rise higher above the level of still water than their hollows fall below it; and the difference between the elevation of the crest and the depression of the hollow is double of the quantity mentioned in Proposition II.

The hydrostatic pressure at each individual particle during the wave-motion is the same as if the liquid were still.

In an Appendix to the paper is given the investigation of the problem, to find approximately the amount of the pressure required to overcome the friction between a trochoidal wave-surface and a wave-shaped solid in contact with it. The application of the result of this investigation to the resistance of ships was explained in a paper read to the British Association in 1861, and published in various engineering journals in October of that year. The following is the most convenient of the formulæ arrived at:—Let w be the heaviness of the liquid; f the coefficient of friction; g gravity; v the velocity of advance of the solid; L its length, being that of a wave; z the breadth of the surface of contact of the solid and liquid; β the greatest angle of obliquity of that surface to the direction of advance of the solid; P the force required to overcome the friction; then

$$P=\frac{f w v^2}{2g} L z (1+4\sin^2\beta+\sin^4\beta).$$

In ordinary cases, the value of f for water sliding over painted iron is ·0036. The quantity $L z\ (1+4\sin^2\beta+\sin^4\beta)$ is what has been called the "augmented surface." In practice, $\sin^4\beta$ may in general be neglected, being so small as to be unimportant.

Some Account of Recent Discoveries made in the Calculus of Symbols.

By W. H. L. Russell, *A.B.*

Before the publication of Professor Boole's memoir on a "General Method in Analysis," which appeared in the 'Philosophical Transactions' for 1844, those mathematicians who adopted the symbolical methods suggested by the researches of Lagrange and Laplace, confined themselves to the use of commutative symbols, and the science was consequently very limited in its applications. It received a fresh impulse from the very remarkable memoir of Professor Boole mentioned above, in which an algebra of non-commutative symbols was invented and applied to the integration of a large class of linear differential equations. It occurred to the author that the proper method of extending the calculus was to construct systems of multiplication and division for functions of non-commutative symbols. This he accordingly effected in his memoir published in the 'Philosophical Transactions' for 1861. As the symbols are non-commutative, two distinct systems of multiplication and division, internal and external, arise for each class of symbols employed.

Let ρ and π be two symbols combining according to the law

$$f(\pi)\,.\,\rho^m=\rho^m f(\pi+m),$$

where $f(\pi)$ is any function of (π), then he gave, in the memoir alluded to, equations to determine the conditions that a symbolical function such as

$$\rho^n\phi_n(\pi)+\rho^{n-1}\phi_{n-1}(\pi)+\rho^{n-2}\phi_{n-2}(\pi)+\ \&c.\ +\phi_0(\pi)$$

may be divisible internally and externally without a remainder by the symbolical function $\rho\psi_1(\pi)+\psi_0(\pi)$, where

$$\phi_n(\pi),\ \phi_{n-1}(\pi),\ \phi_{n-2}(\pi)\ldots\phi_0(\pi),\ \psi_1(\pi)\text{ and }\psi_0(\pi)$$

are all rational functions of (π), or, in other words, that $\rho\psi_1(\pi)+\psi_0(\pi)$ may be an internal or external factor of $\rho^n\phi\ \ (\pi)+\rho^{n-1}\phi_{n-1}(\pi)+$ &c., and also an equation to determine the condition that $\psi_1(\rho)\,.\,\pi+\psi_0(\rho)$ may be an internal factor of

$$\phi_3(\rho)\,.\,\pi^3+\phi_2(\rho)\pi^2+\phi_1(\rho)\,.\,\pi+\phi_0(\rho).$$

He then gave some theorems for the transformation of certain functions of these symbols, which lead to some very curious theorems in successive differentiation: he has treated this part of the subject more fully in the 'Philosophical Magazine' for April 1862. In a subsequent part of his paper in the 'Philosophical Transactions,' he established binomial and multinomial theorems for these symbols, by showing how to expand

$$(\rho^2+\rho\theta(\pi))^n\text{ and }(\rho^\alpha+\rho^{\alpha-1}\theta_1(\pi)+\rho^{\alpha-2}\theta_2(\pi)+\ldots.)^n\text{ in terms of }(\rho)\text{ and }(\pi).$$

At the end of the paper he gave some methods for solving differential equations by a process analogous to the "Method of Divisors" in the theory of algebraical equations. In his second memoir "On the Calculus of Symbols," published in the 'Philosophical Transactions' for 1862, he has shown how we may find the highest common internal divisor of functions of non-commutative symbols, and also how we may resolve them in all possible cases into two equal factors, a process analogous to that for extracting the square root in common algebra. He then investigated the theory of multiplication in this calculus more generally. He gave a rule to find the symbolical coefficient of ρ^m in a continued product of the form

$$(\rho+\theta_1(\pi))(\rho+\theta_2(\pi))(\rho+\theta_3(\pi))\ldots\ldots\ldots(\rho+\theta_n(\pi)).$$

After this he resumed the consideration of the binomial and multinomial theorems explained in the former memoir. He gave the numerical calculation of the coefficients of the general term of the binomial theorem, as explained in the first memoir. In this the expansion was effected in terms of ρ and π, but we may suppose the expansion effected in terms of (ρ) alone. In that case the coefficient of the general term would be symbolical, and a function of (π). He had calculated its value in the memoir, and also the value of the corresponding general symbolical coefficient in the multinomial theorem supposed expanded in powers of ρ alone. He concluded the paper by giving a method to expand the reciprocal binomial $(\pi^2+\theta(\rho)\delta\pi)^n$ in terms of (π). The general cases of division yet remained to be worked. This has been effected by Mr. Spottiswoode in a very able and beautiful paper published in the 'Philosophical Transactions' for 1862. He has there given in full the division of

$$\phi_n(\rho)\pi^n+\phi_{n-1}(\rho)\pi^{n-1}+\phi_{n-2}(\rho)\pi^{n-2}+\&c.\ldots\ldots+\phi_0(\rho)$$

internally and externally by $\psi_1(\rho)\pi+\psi_0(\rho)$; secondly, the division of

$$\phi_n(\rho)\pi\ \ +\phi_{n-1}(\rho)\pi^{n-1}+\phi_{n-2}(\rho)\cdot\pi^{n-2}+\ldots\ldots+\phi_0(\rho)$$

internally and externally by

$$\psi_m(\rho)\pi^m+\psi_{m-1}(\rho)\pi^{m-1}+\psi_{m-2}(\rho)\cdot\pi^{m-3}+\ldots\ldots+\psi_0(\rho);$$

thirdly, the division of

$$\rho^n\phi_n(\pi)+\rho^{n-1}\phi_{n-1}(\pi)+\rho^{n-2}\phi_{n-2}(\pi)+\ldots\ldots+\phi_0(\pi)$$

internally and externally by

$$\rho^m\psi_m(\pi)+\rho^{m-1}\psi_{m-1}(\pi)+\rho^{m-2}\psi_{m-2}(\pi)+\ldots\ldots\psi_0(\pi).$$

He has fully investigated the conditions that the divisor in each case may be an internal or external factor of the dividend, and his results, which are expressed by means of determinants, will be found extremely interesting. The author in conclusion states that he believes the form in which the calculus now stands will be permanent, and that subsequent improvements will be very much based on extending systems of multiplication and division to other symbolical expressions, in which the laws of symbolical combination are different from those here assumed.

On some Models of Sections of Cubes. *By* C. M. WILLICH.

These were carefully-executed models, designed to illustrate certain simple propositions in solid geometry relative to the volumes, &c. of solids formed by the section of a cube by planes. The author wishes, at the same time, to place on record the simple fraction $\frac{148}{167}$, which gives an extremely close approximation to the side of a square equal in area to a circle of which the diameter is unity.

ASTRONOMY.

Some Cosmogonical Speculations. *By* ISAAC ASHE, *M.B.*

The author considered that the present planiform condition of the system disproved the common view that it had formerly been a gaseous sphere, and proved that it had originally been a liquid plane, as Saturn's rings are at present; nor yet in a heated condition, since he thought that, though capable of transformation, heat could no more be absolutely *lost* than its equivalent, motion. The planets had, doubtless, been originally molten; but this heat the author ascribed to the collision of particles, during their formation, from the liquid plane described. This formation he ascribed to the development of a centre of attraction in the liquid plane, and showed how, in a revolving plane, a diurnal rotation from west to east might hence be originated, the particles so attracted acting as a mechanical "couple" of forces on the planet during its formation. From the distance between the interior and exterior planets, he inferred the former existence of two rings, as in the system of Saturn, the asteroids being probably formed from small independent portions of matter between these rings. He considered that the planets also first existed individually as planes, basing this view on the uniformity of plane observed in the orbits of the satellites. The satellites themselves he considered to have been formed from portions of matter left behind during the contraction into a globe of such a plane, which had at first occupied the whole space included within the present orbits of the satellites. This view of the formation of the satellites he based on the fact that the period of diurnal rotation in each of them corresponded with the period of its revolution round its primary, which he showed would be the case with any body whatever, if so left behind or lifted off a planet.

The author then discussed the chemical changes that would ensue on the surface of the earth after it had assumed the globular form. Oxidization of its metallic constituents would absorb a vast proportion of its gaseous matter, and the formation of water would remove a great deal in addition. Hence the absence of atmosphere or water on the moon's surface might be accounted for, as she would carry off with her only $\frac{1}{30}$th portion of the gaseous elements of the planet, and her surface exposed to the chemical action of those elements would be much more than $\frac{1}{30}$th that of the earth. Water also might be quite absorbed on her surface in the formation of hydrates of the alkaline and earthy bases.

On the earth, sodium would unite with chlorine, and common salt would result; and to the large amount of salt so formed the author ascribed the saltness of the ocean; rivers could only carry to the sea salt obtained from soil originally deposited by the ocean, and which must therefore have derived its salt from the sea. This process must be still going on, and hence Dr. Ashe inferred that the sea could never have become salt, or be now increasing in saltness, from that cause; hence he dissented from that view, which was the one universally put forward by geologists.

On a Group of Lunar Craters imperfectly represented in Lunar Maps.

By W. R. Birt, *F.R.A.S.*

One of the objects of lunar maps should undoubtedly be such a representation of the forms of the irregularities of the moon's surface, that a student may readily, at the *suitable epochs*, ascertain the general outlines and configurations of the parts which he is studying, so as to be certain that he has not misapprehended either the position or form of any particular portion of the lunar surface.

A map constructed for a given epoch, *at the full* for instance, that shall give those features by which every crater, mountain-chain, and plain may be *instantly* recognized, is at the present moment a *desideratum*. Indeed, on such a map some craters would not find place. A certain angle of illumination is necessary to bring out saliently the distinguishing features of a crater or mountain-chain; and a series of maps that would exhibit each to the best advantage, must include as many distinct epochs of illumination in their construction as there are meridians encircling the lunar globe.

One of the greatest monuments of the skill and industry characterizing astronomical science is undoubtedly *Beer and Mädler's large map of the Moon*. To the student of selenography it is invaluable; his progress would be slow without it. The writer of this paper cannot, however, agree with Crampton "that every mountain and every valley, every promontory and every defile on the moon's surface, finds its representative on that map." On the *contrary*, in his examination of the lunar surface, he has met with several instances of features not recorded thereon, a recent instance of which forms the subject of the present paper.

In the neighbourhood of a fine chain of craters that come into sunlight from ten to thirteen days of the moon's age, and are well seen under the evening illumination from twenty-one to twenty-four days of the moon's age, lying in the northern regions of the moon from 57° to 74° N. Lat., and from 25° to 50° E. Long., and designated Philolaus, Anaximenes, and Anaximander, with an unnamed crater between Anaximenes and Anaximander, are three crater-form depressions, of which there are numerous examples on the moon's surface,—the usual characteristics being, 1st, an extensive floor, exhibiting a variety of surface in different specimens, often pierced with small craters and diversified with hills; 2nd, a more or less perfect rampart, here and there pierced with craters, and rising into elevated peaks, so that the entire depression is readily recognized as a distinct formation, completely separated from its surrounding neighbours. Two such depressions, lying nearly in the same meridian, and connected by a table-land or plateau, are very imperfectly, if at all, represented by the German selenographers. The sketch accompanying this communication, taken at Hartwell, on Sept. 18, 1862, under the evening illumination, exhibits the general characters of the northern depression, viz. a floor pierced by a line of eruption (a common feature in several lunar forms), a *nearly* continuous rampart on the east and west sides, rising into a considerable mountain mass at the north angle marked B by Beer and Mädler, pierced by the crater Horrebow, and connected by the steep rocks that form the north boundary of the plateau. It is proposed, in accordance with a suggestion by Dr. Lee, to designate this depression "Herschel II."

Beer and Mädler thus describe the table-land:—

"South-easterly of Horrebow is a large plateau, fourteen German miles broad, and from twenty to twenty-five German miles long, appearing less from foreshortening. The western border stretches from the western corner of Horrebow to that of Pythagoras, and is rather steep. An offshoot from the same stretches to Anaximander. The southern boundary is denoted by the crater Horrebow B (+58° 9′ Lat., and −42° 0′ Long.), the northern boundary by two craters *e* and *f* Pythagoras. It rises on the east, in three great steep mountains of a very dark colour, straight up to the plateau, and only faint traces extend from thence still further towards the east. The most southerly of these three mountains is 919 toises high, while all three of the mountains appear to be exactly similar to each other in height, form, and colour.

"The surface of the plateau itself has, besides several craters,—among which Horrebow A (+58° 40′ Lat., and −45° 30′ Long.), 2·67 German miles in diameter, is the largest, deepest, and brightest,—only a few scarcely perceptible ridges, and may accordingly be considered as an actual level. But whether this landscape, containing nearly 200 square German miles, is to be distinctly recognized as one connected whole, depends very much upon illumination and libration."

It is proposed to designate this table-land "Robinson," in honour of the Astronomer of Armagh.

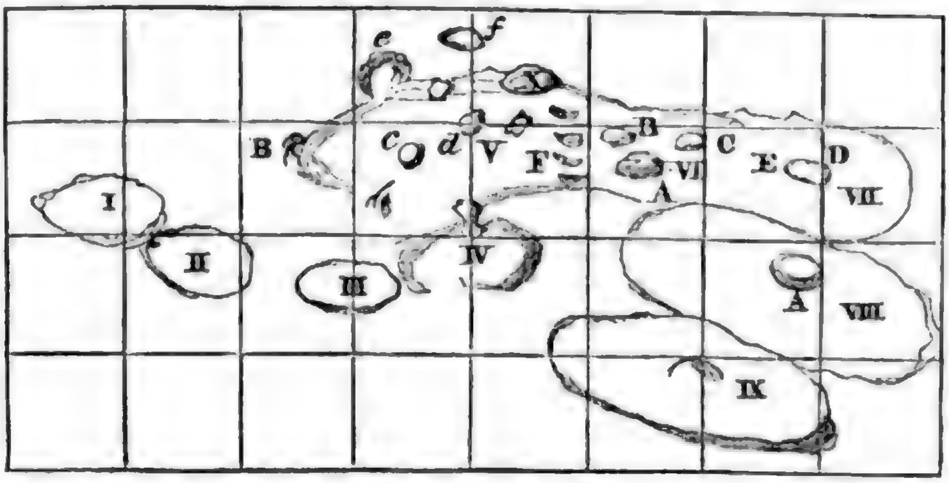
The following description of the same table-land is taken from the author's observations, dated London, 1862, March 12, 6^h to $10^h\ 30^m$ G. M. T., moon's age $12^d{\cdot}13$, morning illumination. Instrument employed, the Royal Astronomical Society's Sheepshanks telescope No. 5, aperture 2·75 inch.

"South of the crater or depression Herschel II. is another, well defined, but not so large. Between the two is a table-land, in which at least five craters have been opened up. Two are in a line with Horrebow; both are given by Beer and Mädler; the northern one is marked B [Horrebow B], the southern is undesignated. The principal crater in this table-land is marked A by Beer and Mädler [Horrebow A]; the three form a triangle: the two remaining craters are near together, and nearly east of A; the largest is marked *d* by Beer and Mädler, the other *e*. All the craters are shown on the map. [*Note.*—The crater *d* is referred to in the foregoing translation as *f* Pythagoras; Beer and Mädler thus speak of it:—"Through an oversight, the lettering Pythagoras *d* occurs twice on our map; once for a slightly depressed crater on the edge of the previously-described plateau."]

"The table-land lies nearly in the direction of the meridian: the mountains on the north slope, or rather their rugged and precipitous slopes, dip towards the large crater Herschel II.; while those on the south [the three dark mountains before mentioned] dip towards the other and smaller crater, which it is proposed to designate 'South.' On the west the table-land abuts on the border of the Mare Frigoris, while on the east it extends to some mountain-ranges beyond Anaximander."

[The reader will notice a discrepancy in the descriptions as regards the points of the lunar horizon. It was thought better to leave each description as given by the writers, rather than attempt a conversion of them; especially as future observers can decide upon which they will adopt, consistent with the principles of lunar topography.]

The form of the table-land before described is irregular. In the sketch it appears to be confined to the area between Herschel II. and "South," and this is the most conspicuous portion of it; but on the night of the 31st of January, 1863, under the *morning illumination*, it was seen to extend to the north of a crater then coming into sunlight eastward of "South," which it is proposed to designate "Babbage." A chain of mountains, connecting "Babbage" with Anaximander, forms the eastern boundary of the table-land. Beer and Mädler have left its boundaries undetermined, and further observations are necessary to mark them out with precision.



Eye-sketch of a chain of Lunar craters, with three large unnamed and unrepresented craters, taken at Hartwell on the morning of Sept. 18, 1862.

I. Philolaus (Riccioli). A ringed mountain.

II. Anaximenes (Riccioli). A ringed mountain.

III. An unnamed crater on Beer and Mädler's map. It is marked "Sommering" by Le Couturier. Beer and Mädler have another "Sommering" near the centre of the disk.

IV. Anaximander (Riccioli). The ring of this crater is imperfect, and requires further observation to define its outline accurately. Between it and V there is a well-marked mountain, besides other interesting features.

V. Herschel II. (Birt). An extensive depression of the character of a walled plain, with a nearly perfect ring not shown by Beer and Mädler, who describe the region between Horrebow, Anaximander, and Fontenelle as an exceedingly rich crater country; the principal part consisting of the region of Herschel II.

The following features are common to the eye-sketch and Map:—

B. A high mountain mass marked Anaximander B by Beer and Mädler. It really forms the north angle of the wall of the large depression Herschel II.

e. A mountain mass forming the N.W. angle of the ring of Herschel II.

f. A crater exterior to Herschel II.

c, *d.* Two craters in the line of eruption that crosses Herschel II. in a curvilinear direction.

The eye-sketch shows the general direction of this eruptive line from the portion of the ring that is absent to a crater east of Horrebow (X). It is not shown on the German map.

VI. The table-land "Robinson" (Birt).

A, B, and C. Craters on the table-land.

E. A steep mountain "steppe" on the south, not shown in the sketch, dipping to the depression "South." It contains the three dark mountains of Beer and Mädler.

F. A steep mountain "steppe" on the north, dipping to Herschel II.

E and F were observed and figured by Schröter in his 'Selenotopographische Fragmente,' T. xxvi. fig. 1.

VII. A depression south of the table-land "Robinson." Proposed name "South" (Birt). The central crater D is shown by Beer and Mädler.

VIII. Another depression eastward of "South," and between it and Pythagoras. The crater A on Beer and Mädler's map is really nearer the west border than shown in the eye-sketch. Proposed name "Babbage" (Birt).

Schröter observed this walled plain. Figures of it, with the interior crater A close to the western edge, are given in T. xxvi. (figs. 1 and 2) of his 'Selenotopographische Fragmente.' It would appear that he designated it "Pythagoras," the crater now bearing that name being termed Pythagoras borealis. By far the most suitable name for the large crater with the central mountain is that on the large

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German map, "Pythagoras;" while to prevent misapprehension as to the western walled plain with the included crater, and to distinguish it from the eastern crater, it is proposed to call it "Babbage."

IX. Pythagoras (Riccioli). The largest and most magnificent crater in this part of the moon, showing itself as a conspicuous object with its central mountain, when nearly the whole of the previously-described craters and walled plains are lost to view.

X. Horrebow (Schröter). This crater, which pierces the S.W. angle of the rim of Herschel, has hitherto been treated as being independent of any other formation. Schröter, who named it, figured it in its proper position at the west of the mountains F, and he gives (see T. xxvi. fig. 1, above referred to) the chain of mountains, omitted by Beer and Mädler, forming the continuation of the rim from the steep mountains F to the rim of Anaximander, where he gives a small crater shown in the eye-sketch. On the other hand, Schröter has omitted the western rim extending northwards from Horrebow, which is given by Beer and Mädler. Horrebow is clearly a part of Herschel II.

Schröter does not appear to have recognized or figured "South."

On the Augmentation of the Apparent Diameter of a Body by its Atmospheric Refraction. By the Rev. Professor CHALLIS, *M.A., F.R.S., F.R.A.S.*

For reasons given in another communication, it was assumed that atmospheres generally have definite boundaries at which their densities have small but finite values. Two cases of refraction were considered: in the one, the curvature of the course of a ray through the atmosphere was assumed to be always less than that of the globe it surrounds; and in the other, the curvature of the globe might be the greater. The former is known to be the case with the earth's atmosphere; and it was supposed that, *à fortiori*, this must be the case with respect to any atmosphere the moon may be supposed to have. On this supposition it was shown that the apparent diameter of the moon, as ascertained by measurement, would be greater than that inferred from the observation of an occultation of a star, because, by reason of the refraction of its atmosphere, the star would disappear and reappear when the line of vision was within the moon's apparent boundary. The same result would be obtained from a solar eclipse. It was stated that, by actual comparisons of the two kinds of determinations, such an excess to the amount of from 6″ to 8″ was found. This difference may reasonably be attributed to the existence of a lunar atmosphere of very small magnitude and density. The author also stated that from this result there would be reason to expect, in a solar eclipse, that a slender band of the sun's disk immediately contiguous to the moon's border would be somewhat brighter than the other parts, and advised that especial attention should be directed to this point on the next occurrence of a solar eclipse. The case in which the curvature of the path of the ray is greater than that of the globe was assumed to be that of the sun's atmosphere; and it was shown, on this supposition, that all objects seen by rays which come from the sun's periphery are brought by the refraction to the level of the boundary of the atmosphere, whether they proceeded from objects on the surface of the interior globe, or from clouds supposed to be suspended in the atmosphere. Accordingly, the contour of the sun should appear quite continuous, and the augmentation of apparent semidiameter will be equal to the angle subtended at the earth by the whole height of the atmosphere. The apparent diameters of the planets will, for like reasons, be augmented to a certain amount by their atmospheric refractions; and on account of the great distances of these bodies from the earth, the eclipse of a satellite will take place as soon as the visual ray is bent by the interposition of the atmosphere.

On the Zodiacal Light, and on Shooting-Stars.
By the Rev. Professor CHALLIS, *M.A., F.R.S., F.R.A.S.*

The phenomena of the zodiacal light, as gathered from observations made both in northern and in southern latitudes, were stated to be as follows. As seen in north latitudes, it appears in the West after the departure of twilight, as a very faint light, stretching along the ecliptic, about 10° broad at its base in the horizon, and coming to an apex at an altitude of from 40° to 50°. It is most perceptible in the West in the months of February and March, at which time its apex is near the Pleiades. Similar appearances are presented in the morning before sunrise in the East in the months of August and September. The light seen in the autumn lies in the *same* direction from the sun as that seen in the spring. In the southern hemisphere the appearances are strictly analogous, but the times and positions of maximum visibility are, the evenings in autumn in the West, and the mornings in spring in the East. The portion best seen in the southern hemisphere lies in the *opposite* direction from the sun to that which is best seen in the northern hemisphere. The portion seen, and the degree of visibility, depend on the inclination to the horizon of the part of the ecliptic along which the light stretches. The greater the inclination the better it is seen. At the December solstice opposite portions have been seen in the northern hemisphere, one in the morning and the other in the evening; and in the southern hemisphere opposite portions have been similarly seen at the June solstice. At these seasons the ecliptic is inclined at large and equal angles to the horizon at equal intervals before sunrise and after sunset. The southern observations, from which these inferences are drawn, are those made by Professor Piazzi Smyth at the Cape of Good Hope in the years 1843, 1844, and 1845, and published in vol. xx. of the 'Edinburgh Transactions,' and *evening* observations in the *autumn* of 1848, communicated by a friend of the author resident in the interior of Brazil. More recently, in vol. iv. of the 'American Astronomical Journal' were published observations by Mr. Jones, a chaplain of the United States Navy, who makes the following statement:—"When in latitude 23° 28′ N., the sun being in the opposite solstice, I saw the zodiacal light at both east and west horizon simultaneously from eleven to one o'clock for several nights in succession." The ecliptic must at the time have nearly passed through the zenith of the observer at midnight. It is clear, therefore, that to be seen an hour before and after midnight, *the zodiacal light must have extended beyond the earth's orbit.* Taking this as a necessary inference from the observations, it follows that the earth is either always enveloped by the zodiacal light, or at least when passing through the line of its nodes. Professor Challis considers this to be the explanation in part of the luminosity of the sky which is generally perceptible on clear nights, and at some seasons in greater degree than at others. The American observer also states that he saw when at Quito, "every night, and all through the night, a luminous arch from east to west quite across the sky, 20° wide, and most apparent when the ecliptic is vertical." This light is distinguished from the zodiacal light by its being of uniform width.

From the *ensemble* of the observations, the zodiacal light is of the form of a double convex lens, with the sun in the centre, and the principal plane coinciding nearly with that of the sun's equator. As it may be inferred from the foregoing statements that it envelopes the earth, we may conclude that it is simply *luminosity*, without accompanying bodies. Professor Challis proposes, therefore, to account for it by the effect which the rotation of the vast body of the sun produces on the luminiferous medium, this effect being rendered visible by the disturbance of the gyratory motion by the motion of translation of the sun in space. In a similar manner, magnetic currents are rendered visible in the form of the aurora by the effect of transverse currents. This explanation he stated to be in accordance with the principles of the undulatory theory of light.

The appearance of shooting-stars in the August and November periods was accounted for on like principles, by the disturbance given to the luminiferous medium by the curvilinear motion of the earth resulting from its proper motion and the motion of the solar system through space. At two epochs depending on the variations of the rate of motion, and of the rate of deviation from rectilinear motion, the disturbances would be at a maximum, and these two epochs were assumed to correspond to Aug. 10 and Nov. 12. The kind of disturbance which the earth impresses by its curvilinear motion was supposed to be such as would produce eddies or whirls. Besides this, there might be a disturbance of terrestrial origin, analogous to that which produces the zodiacal light, which might account for the luminous arch noticed by the American observer.

On some of the Characteristic Differences between the Configuration of the Surfaces of the Earth and Moon. By Professor HENNESSY, *F.R.S.*

The author pointed out that the peculiarities observed on the surface of our satellite should be ascribed to the sole action of volcanic forces, whereas those which we find on the earth result from a combination of volcanic and atmospherical agencies. In order more perfectly to study these contrasts, he called attention to the most characteristic feature of all lunar volcanos, namely the ring- or hoop-shaped crater, surrounded by circular, nearly concentric ridges. On the earth's surface, volcanos deviated more or less from this type; and if the deviations are due to the differences between terrestrial and lunar superficial forces, it must follow that such differences will be most distinctly manifested in those cases where such terrestrial forces possess the highest degree of energy. He illustrated this proposition by referring to the peculiar structure of the volcanos in the island of Java, where the action of tropical rains and hurricanes has been effective in producing the widest differences between the terrestrial volcanic summits and those observed on the moon's surface. While the hooped structure of the latter cannot be traced among the views of Javanese volcanos which are presented in the comprehensive work published by Dr. Junghuhn, we frequently find diagrams of volcanic cones showing radiating ribs like those of a folded lamp-shade or an umbrella half closed, an appearance due to the very regular manner in which the tropical torrents scoop out the friable and scoriaceous summits of the craters. The contrast which arises by comparing some of these drawings with the best lunar diagrams and photographs may prove highly interesting to geologists as well as to selenographers.

On a Brilliant Elliptic Ring in the Planetary Nebula, Æ 20° 56′, N.P.D. 101° 56′. By WILLIAM LASSELL, *F.R.S.*; *in a Letter to* Dr. LEE, *F.R.S.*

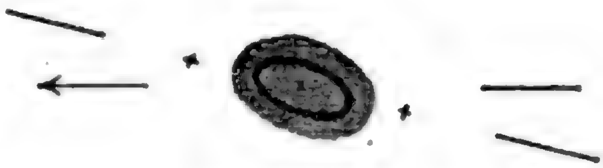
9 Piazza Sliema, Malta, 26th Sept. 1862.

MY DEAR SIR,—In directing my large equatorial upon the well-known planetary nebula situated in Æ $20^h\ 56^m$, N.P.D. 101° 56′ (1862), it has revealed so marvellous a conformation that I cannot forbear to send you a drawing of it, with some description of its appearance. With comparatively low powers, *e. g.* 231 and 285, it appears at first sight as a vividly light-blue elliptic nebula, with a slight prolongation of the nebula, or a very faint star at or near the ends of the transverse axis. In this aspect the nebula resembles in form the planet Saturn when the ring is seen nearly edgewise. Attentively viewing it with higher powers, magnifying respectively 760, 1060 and 1480 times, and under the most favourable circumstances which have presented themselves, I have discovered within the nebula a brilliant elliptic ring, extremely well defined, and apparently having no connexion with the surrounding nebula; which indeed has the appearance of a gaseous or gauze-like envelope, scarcely interfering with the sharpness of the ring, and only diminishing somewhat its brightness. This nebulous envelope extends a little further from the ends of the conjugate than from the ends of the transverse axis; indeed it is but very faintly prolonged, and only just traceable towards the preceding and following stars. There is a star near its border northwards, in the projection of the conjugate axis.

The breadth or thickness of the ring is, unlike that of Saturn, nearly uniform or equal in every part, so that its form most probably is either really elliptic, and seen by us in a line nearly perpendicular to its plane; or if really circular and seen foreshortened, a section through any part of it limited by the internal and external diameters must be a circle. In other words, it will be like a circular cylinder bent round. It could scarcely fail to bring to my mind the annular nebula in Lyra, especially as there is a conspicuous central star (proportionally, however, much brighter than that which is in the centre of that nebula); and yet the resemblance is only rudely in form; for this ring is much more symmetrical and more sharply defined, suggesting the idea of a solid galaxy of brilliant stars.

The ring is not *perfectly* uniform in brightness, the south-preceding part being slightly the most vivid. The transverse axis is inclined to the parallel of declination about 13°. A series of micrometrical measures of the length and breadth of the ellipse, gives a mean of 26″·2 for the transverse, and 16″·6 for the conjugate axis.

The accompanying drawing has not been at all corrected by these measures, but is the result of several sketches made during different observations, and is a faithful transcript of the appearance of the nebula to my eye, when most favourably seen.



The object is, as may be supposed, one of extreme difficulty, requiring in the highest degree the combination of light and definition in the telescope, and a favourable state of atmosphere,—which will further appear when I state that it was not until I was favoured with an unusually fine night, and had applied a power of 1480, that the whole of the details were brought out.

I confess I have been greatly impressed by the revelation of this most wonderful object, situated on what perhaps we may consider as the very confines of the accessible or recognizable part of the universe, affording ground for the inference that more gorgeous systems exist beyond our view than any we have become acquainted with.
I am, &c., W. LASSELL.

Observed R.A. and N.P.D. of Comet II. 1862.

By the Rev. R. MAIN, *M.A., F.R.S.*

This paper gave the results of observations of the comet from August 5 to August 29, on ten nights. It was observed on the meridian with the Carrington transit-circle on August 7 and 9, and off the meridian with the heliometer, used as an ordinary equatorial, on August 5, 7, 9, 14, 18, 19, 22, 23, 25, and 29. The observations have been rigorously reduced, and all necessary corrections for refraction, parallax, &c. have been applied. The assumed mean places of the companion stars for 1862, January 1, taken mainly from the 'Radcliffe Catalogue of Circumpolar Stars,' were also given.

On the Dimensions and Ellipticity of Mars.

By the Rev. R. MAIN, *M.A., F.R.S.*

This paper gave the results of seven sets of measures of the disk of Mars, made for the determination of his ellipticity with the heliometer, by the method of contact of limbs of the two images formed by the half-object-glasses. The power used was 300, which is found by experience to be very suitable for such measures. The direction of the polar diameter was determined by a well-defined circular white cap near the southern limb, the centre of which was assumed to be coincident with the South Pole. The directions, separately estimated, of the polar and equatorial diameters agreed well on separate evenings, their difference never deviating much from 90°, thus proving the precision of the estimations. The measured diameters have been corrected for defect of illumination.

The following are the results of the measures:—

	Polar diam.	Equat. diam.	Ellipticity.
	″	″	
1862, Sept. 18	21·844	22·386	$\frac{1}{41\cdot3}$
„ 19	22·345	22·986	$\frac{1}{35\cdot9}$
„ 22	22·704	22·974	$\frac{1}{85\cdot1}$
„ 23	22·138	22·911	$\frac{1}{29\cdot6}$
„ 25	22·551	23·106	$\frac{1}{41\cdot6}$
„ 27	22·519	23·125	$\frac{1}{38\cdot2}$
„ 30	22·896	23·012	$\frac{1}{198\cdot4}$

Mr. Main drew particular attention to the difference in the degrees of consistency in the results for the polar and for the equatorial diameter, the latter agreeing surprisingly well from night to night, while the former exhibit discordances of considerable amount. This it is difficult to account for, except on the supposition that the snowy cap before referred to may have had some influence in distracting the eye from the real borders of the images in making the contacts. Still, on the whole, the measures all agree in establishing a measurable ellipticity, and Mr. Main intended to continue them at every opportunity during the present opposition, with the utmost care and caution.

On some Peculiar Features in the Structure of the Sun's Surface.

By J. Nasmyth.

The author gave a short sketch of the character of the sun's surface as at present known. He described the spots as gaps or holes, more or less extensive, in the luminous surface or photosphere of the sun. These exposed the totally dark nucleus of the sun; over this appears the mist surface—a thin, gauze-like veil spread over it. Then came the penumbral stratum, and, over all, the luminous stratum, which he had discovered was composed of a multitude of very elongated, lenticular-shaped, or, to use a familiar illustration, willow-leaf-shaped masses, crowded over the photosphere, and crossing one another in every possible direction. The author had prepared and exhibited a diagram, pasting such elongated slips of white paper over a sheet of black card, crossing one another in every possible direction in such multitudes as to hide the dark nucleus everywhere, except at the spots. These elongated lens-shaped objects he found to be in constant motion relatively to one another; they sometimes approached, sometimes receded; and sometimes they assumed a new angular position, by one end either maintaining a fixed distance or approaching its neighbour, while at the other end they retired from each other. These objects, some of which were as large in superficial area as all Europe, and some even as the surface of the whole earth, were found to shoot in thin streams across the spots, bridging them over in well-defined streams or comparative lines, as exhibited on the diagram; sometimes by crowding in on the edges of the spot they closed it in, and frequently, at length, thus obliterated it. These objects were of various dimensions, but in length they generally were from 90 to 100 times as long as their breadth at the middle or widest part.

Observations on Three of the Minor Planets in 1860.

By Norman Pogson. *Communicated by* Dr. Lee, *F.R.S.*

Observations of Minor Planets made at Hartwell in 1860.

Greenwich Mean Time.	App. R.A.	App. P. D.	(Log.Par.	× Δ.)	Comparisons.
Eunomia ⑮.					
h m s	h m s	° ′ ″	R. A.	P.D.	
1860, Sept. 1. 12 14 46	21 35 50·07	90 51 31·6	+9·089	−0·832	6 with *g*
„ „ 1. 12 57 59	21 35 48·34	90 51 41·0	+9·262	−0·831	12 „ *g*
„ „ 4. 10 57 59	21 33 16·34	90 54 41·5	+8·454	−0·832	7 „ *p*
„ „ 7. 11 35 5	21 30 48·18	90 58 17·4	+9·027	−0·832	5 „ *o*
Olympia (59).					
1860, Sept. 25. 12 4 13	0 31 0·68	90 49 23·4	−8·195	−0·832	12 with *n*
„ Oct. 2. 13 24 59	0 25 52·73	91 53 56·0	+9·190	−0·837	10 „ *m*
„ „ 3. 9 38 14	0 25 16·45	92 1 29·3	−9·426	−0·805	6 „ *m*
„ „ 3. 10 55 11	0 25 14·09	92 1 57·3	−8·990	−0·835	6 „ *m*
Thalia ㉓.					
1860, Sept. 25. 13 4 37	0 11 55·55	104 34 25·3	+9·039	−0·891	8 with *l*
„ Oct. 3. 12 28 38	0 4 38·05	105 3 11·1	+9·056	−0·892	10 „ *k*

The first observation of Eunomia was made with the parallel wire micrometer, and power 110; all others with the ring micrometer, and power 84 of the Hartwell Equatorial. The comparison stars employed were as in the annexed list:—

Ref.		Authority.	Mag.	Mean R. A. 1860.	Mean P. D. 1860.
				h m s	° ′ ″
k	*a*	Oeltzen Arg. 33 & 34=9 Lalande (weight ⅛).	89	0 3 16·86	105 13 43·0
l	*b*	Weisse 0·227.	9	0 13 40·42	104 24 31·4
m	*c*	11 Ceti; Mädler's Bradley 36; 78 Robinson.	78	0 22 44·01	91 53 20·9
n	*d*	Weisse 0·592.	9	0 34 46·05	90 47 32·5
o	*n*	4704 Robinson.	7	21 30 22·25	91 0 56·3
p	*o*	24 Aquarii; Mädler's Bradley 2·816.	7	21 32 18·44	90 41 1·3
q	*p*	Weisse xxi. 916=42598 Lalande (weight ½).	9	21 38 11·65	90 51 2·9

The following magnitudes have been carefully estimated; generally, by comparison with apparently similar objects in the nearest variable star-map then in course of construction:—

Victoria, 1860, April 3...... 10·5 mag.
Thetis „ „ 9...... 10·5 „
Metis „ Sept. 1...... 9·0 „
Eunomia, Sept. 1, 8·2; Sept. 4, 8·6; Sept. 7, 8·3.
Olympia, Sept. 25, 9·6; Oct. 3, 10·2.
Amphitrite, Oct. 3, 9·0.
Thalia, Sept. 7, 11·0; Sept. 10, 11·2; Sept. 13, 11·0; Sept. 25, 11·0; Oct. 3, 11·5.

The preceding observations of minor planets were the last made by Mr. Pogson before leaving England for Madras in January 1861; it was his intention to reduce them speedily, and to send them to me from Malta or Alexandria; but, as anticipated, the inconveniences of a sea-voyage prevented him from fulfilling his design, and the pressure of official duties in his new position has not permitted him to attend to his former unfinished pursuits until recently.

On the Excentricity of the Earth, and the Method of finding the Coordinates of its Centre of Gravity. By W. Ogilby, *F.G.S.*

On the probable Origin of the Heliocentric Theory. By J. Schvarcz.

The author traced the origin of the Copernican system to Pythagoras, through Aristarchus the Samian and Archimedes of Syracuse.

On Autographs of the Sun. By the Rev. Professor Selwyn.

The author showed several "autographs of the sun," taken with his "heliautograph" by Mr. Titterton, photographer, Ely, which consists of a camera and instantaneous slide by Dallmeyer, attached to a refractor of 2¾ inches aperture by Dollond; the principle being the same as that of the instrument made, at the suggestion of Sir J. Herschel, for the Kew Observatory. The autographs are of July 25, 26, 28, 29, 31; August 1, 2, and August 4, 10.15 A.M. and 11.30 A.M. (a series of bright days coincident with a large group of spots); August 19, 20, 23 and 25, where the same group reappears, much diminished; September 19, 23, 26, 30, Oct. 1, in which is seen a group of 118,000 miles in length. On the 23rd three autographs were taken, two of them with the edge of the sun in the centre of the photographic plate, showing that the diminution of light towards the edges of the disk is a real phenomenon, and not wholly due to the camera. In the two of the 4th of August, where the great spot (20,000 miles in diameter) appears on the edge, a very distinct *notch* is seen, and the sun appears to give strong evidence that the spots are cavities; but eye observations and measurements by the Rev. F. Howlett, and others, tend to show that this evidence is not conclusive, for there was still a remaining portion of photosphere between the spot and the edge. The phenomena shown in these autographs appear to confirm the views of Sir J. Herschel, that the two parallel regions of the sun where the spots appear, are like the tropical regions of the earth where tornadoes and cyclones occur, and those of Wilson in the last century. The *faculæ* are clearly shown, and seem to prove that the tropical regions of the sun are highly agitated, and that immense waves of luminous matter are thrown up, between which appear the dark cavities of the spots, whose sloping sides form the penumbræ, as explained by Wilson and others. Other analogies between solar spots and earthly storms were pointed out, and reference was made to the glimpses of the structure of the sun exhibited by Mr. Nasmyth as confirming the above views.

On the Hindû Method of Calculating Eclipses. *By* W. Spottiswoode, *F.R.S.*

The astronomy of the Hindus is contained in a series of works known by the general name of "Siddhanta." These have been composed at different times over a period of 2000 years. In them are some incidental allusions to the configurations of the heavenly bodies, by means of which Baily, Davis, and others have attempted to calculate the dates of some of the works. There were two points to which the author drew particular attention, viz. the process of correction whereby the true longitudes were deduced from the mean, and the precession of the equinoxes. It had been noticed that the apsides, or points of slowest movement, and the positions of conjunction with the sun had proper motions. These were attributed to influences residing in the apsides and conjunctions respectively, and corrections due to each were accordingly devised. The undisturbed orbit was considered a circle, with the earth (E) in the centre, and upon it the centre of a smaller circle or epicycle moved with a uniform angular velocity equal, but opposite in direction, to that of the undisturbed planet; so that M being the centre, and *m* any given point on the epicycle, M*m* always remained parallel to itself. If, then, at the apse or conjunction (according as the correction of one or the other was being calculated) M*m* was in a straight line with EM, the true position of the planet was conceived to be at the point where E*m* cut the undisturbed orbit. The radius, moreover, of the epicycle was variable, and its magnitudes at the odd and even quadrants being determined so as to satisfy observation, its intermediate variation was considered proportional to the sine of the mean anomaly. The precession of the equinoxes is an important element in Hindû astronomy, not only as a question of scientific accuracy, but also as marking an epoch in the history of discovery. It is an ascertained fact that their earlier writers, among the foremost of whom Brahmagupta may be mentioned, took no account of it whatever. The statement in the Surya Siddhanta, when divested of its obscure terminology, seems to amount to this, that the sidereal circle shifts on the zodiac with an oscillating motion, whose period is 7200 years, and whose maximum range is 27°. This gives an annual rate of 54".

On some Improved Celestial Planispheres. *By* C. J. Villa.

Light and Heat.

On the Means of following the Small Divisions of the Scale regulating the Distances and Enlargement in the Solar Camera. *By* A. Claudet, *F.R.S.*

The author, in a former paper, had proposed a new method for measuring both the distances of the negative and screen for any degree of enlargement of the image, by means of a scale or unity divided into 100 parts, and smaller fractions if possible. This scale being fixed on the table of the optical apparatus, an index connected with the frame holding the negative was brought exactly on any division of the scale which was indicating the proportion and distance of the image. This arrangement would be very complete and satisfactory if the scale were always long enough to be marked with divisions sufficiently conspicuous; but the shorter the focus of the object-glass, the smaller the divisions of the scale must be. In order to meet this difficulty, he has adopted the following plan:—He traces on the table an equilateral triangle, the base of which is the exact length of the scale. Taking 8 inches, for example, as that length, the three sides of the triangle will be 8 inches. Now, it is possible to enlarge the base three, four, five, or any number of times, by extending the sides of the triangle in the same ratio; so that if it be desirable to enlarge the scale four times, a triangle is formed having its base four times longer, viz. equal to 32 inches; and dividing this new base into 100 parts, it is evident that each division will be four times larger than it could have been on the original base. Now, describing an arc, the chord of which is the base of the triangle, and attaching to the summit a thin metallic wire, the other end of which can slide on the arc, it is evident that each division of the magnified scale which may be covered by the wire will correspond exactly with an equal division of the original scale, so that, after having brought the metallic wire on the division of the increased scale indicating the size of the required image, and the wire being fixed on the index, it will be brought exactly on any division of the unity of measure, however small it may be. The author has described another plan to obtain the same result, and, perhaps, more effectively: it consists in fixing the negative on a rack exactly the length of the scale, which, acting on a pinion adapted to a sufficiently large wheel containing the requisite divisions, will produce an entire revolution of the wheel; and an index being fixed on the table, will indicate on the wheel the exact amount of the course effected by the negative on the scale; and by turning the wheel to the division required, this will bring the negative with the greatest accuracy to the distance corresponding with the division. This system of focusing all camera-lenses might be very advantageous in photographic operations, and would be less subject to errors than the usual way of focusing on the ground glass.

Relation entre les Phénomènes de la Polarisation Rotatoire, et les Formes Hémièdres ou Hémimorphes des Cristaux à un ou à deux Axes Optiques.

Par A. Des Cloizeaux.

Tout le monde sait que la découverte de la polarisation de la lumière a rendu possible l'institution de nombreuses recherches, inabordables à tout autre mode d'observation, sur la constitution moléculaire des corps solides et liquides. Je n'entreprendrai pas ici de passer en revue les faits intéressants et les lois remarquables dont on doit la connaissance aux travaux des Malus, des Fresnel, des Herschel, des Arago, des Brewster, des Biot, &c. Je m'occuperai seulement de la polarisation rotatoire et des relations que ce phénomène peut avoir avec la structure physique des corps cristallisés. Depuis que la science a été dotée des microscopes polarisants d'Amici et de Nörrenberg, on a pu étendre les observations optiques à un grand nombre de substances trop peu transparentes ou de trop petites dimensions pour se prêter à l'emploi des instruments généralement usités jusque dans ces dernières années. Le quartz est resté pendant très longtemps le seul corps solide dans lequel on eut constaté l'existence du pouvoir rotatoire, et Sir John Herschel a le premier fait remarquer qu'il paraissait y avoir une relation constante entre le sens de la rotation des cristaux et le sens suivant lequel s'enroule la spirale formée par plusieurs des faces connues sous les noms de faces plagièdres et par la face rhombe, lorsque l'axe principal des cristaux est placé verticalement devant l'observateur. Ce rapprochement a conduit à regarder le phénomène de la polarisation rotatoire comme dû à un arrangement particulier des molécules physiques qui se manifesterait quelquefois par des formes cristallines présentant l'hémiédrie dite plagièdre ou tournante. On sait que le caractère de cette hémiédrie est la non-superposition des solides symétriques résultant de la réunion des faces plagièdres situées à droite et à gauche d'une même face prismatique du quartz. L'observation prouve d'ailleurs qu'elle peut s'allier avec l'hémiédrie qui fournit pour la face rhombe deux solides inverses mais superposables. Il est en effet probable que c'est une structure de ce genre qui donne aux cristaux *dextrogyres* et aux cristaux *lévogyres* la propriété d'imprimer à la lumière polarisée des modifications de sens contraire; car on n'a jamais observé de phénomènes rotatoires dans les cristaux d'apatite, de Schéelite, d'érythroglucine, &c., sur lesquels on ne connait jusqu'à présent que des formes hémièdres superposables. Malheureusement la dissymétrie intérieure n'est pas toujours accusée par des signes extérieurs, et l'observation seule indique si un corps cristallisé possède ou ne possède

pas la polarisation rotatoire. Ainsi, un grand nombre de cristaux de quartz ne portent aucune face plagièdre; le chlorate de soude, dans les cristaux duquel M. Marbach a découvert le pouvoir rotatoire, s'obtient tantôt en cubes parfaits, tantôt en tétraèdres simples ou en tétraèdres modifiés par les faces d'un dodécaèdre pentagonal qui occupent relativement à celles du tétraèdre deux positions inverses l'une de l'autre en rapport avec le sens de la rotation; le cinabre rhomboédrique et le sulfate de strychnine quadratique, qui, d'après mes observations, impriment aussi au plan de polarisation une déviation égale, pour le premier à 16 fois et pour le second à la moitié de celle que produit le quartz, n'ont offert jusqu'ici aucune trace d'hémiédrie; cependant j'ai trouvé dans le cinabre des cristaux dextrogyres, des cristaux lévogyres, et des cristaux complexes où l'emploi de la lumière polarisée convergente manifeste les spirales d'Airy absolument comme dans le quartz. La cause qui donne naissance à la polarisation rotatoire dans les cristaux paraît donc indépendante de celle qui produit les formes hémiédriques; seulement, comme l'a fait voir M. Marbach, la production de ces formes peut être favorisée artificiellement en faisant varier les conditions dans lesquelles s'opère la cristallisation. Il est donc probable que les cristaux de quartz à faces plagièdres n'ont pas pris naissance dans les mêmes circonstances que ceux où les faces plagièdres manquent; tous les cristaux de cinabre connus jusqu'à ce jour ont dû au contraire se former sous l'influence de phénomènes géologiques semblables.

Depuis que M. Biot a découvert la déviation imprimée au plan de polarisation par certains liquides et certaines dissolutions, on s'est souvent demandé si les dissolutions actives susceptibles de cristalliser produisaient nécessairement des cristaux doués du pouvoir rotatoire. La plus grande partie des substances actives en dissolution cristallisant sous des formes qui possèdent deux axes optiques, la question est longtemps restée sans réponse expérimentale. Mais les travaux de M. Marbach et les miens, en révélant l'existence des trois seuls cas réalisables dans les cristaux dépourvus de la double réfraction ou dans les cristaux à un seul axe optique, semblent prouver que les deux genres de phénomènes sont indépendants l'un de l'autre.

En effet, 1°, le chlorate de soude, inactif en dissolution dans l'eau, jouit du pouvoir rotatoire lorsqu'il est en cristaux; le quartz fondu ou à l'état de silice soluble et le quartz cristallisé présentent les mêmes différences.

2°. Le sulfate de strychnine quadratique à 13 équivalents d'eau, en dissolution comme en cristaux, dévie à gauche le plan de polarisation, seulement le pouvoir rotatoire des cristaux est environ 30 fois plus grand que celui de la dissolution.

3°. Le camphre ordinaire des laurinées, actif en dissolution et à l'état fondu, donne par sublimation des cristaux appartenant au système hexagonal, dans lesquels on ne peut constater aucune déviation du plan de polarisation, même sous une épaisseur de plusieurs millimètres.

Les cristaux à deux axes optiques, dont la dissolution possède le pouvoir rotatoire, sont assez nombreux; on a donc pu les soumettre à des expériences variées. D'après les recherches de M. Pasteur, l'existence du pouvoir rotatoire dans une dissolution serait le plus souvent (à l'exception des sulfamylates) accompagnée par l'hémiédrie non superposable ou l'hémimorphie d'une ou de deux des formes simples que présentent les cristaux dissous. Cette hémiédrie se montre d'ailleurs quelquefois sur les cristaux formés naturellement au sein d'une dissolution dans l'eau pure, d'autres fois elle doit être provoquée, soit en faisant varier la nature du dissolvant, soit en blessant les cristaux et les replaçant dans leur eau-mère*. S'il existe, comme pour l'acide tartrique, les tartrates et quelques autres substances d'origine *organique*, deux dissolutions, l'une *lévogyre* et l'autre *dextrogyre*, les formes hémièdres ou hémimorphes correspondantes produisent ordinairement (le sel de seignette potassique paraît seul faire exception) deux solides symétriques mais non superposables. La réciproque n'est pas vraie dans tous les cas, puisque le sulfate de magnésie et le formiate de strontiane, dont les cristaux offrent l'hémiédrie non superposable, fournissent des dissolutions inactives. Les causes qui produisent les formes cristallines hémièdres paraissent donc agir d'une manière plus générale que celle à laquelle est dû le pouvoir rotatoire moléculaire.

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* Ann. de Chimie et de Physique, tom. xxxviii. et xlix.

On the Cohesion of Gases, and its relations to Carnot's *Function and to recent Experiments on the Thermal effects of Elastic Fluids in Motion. By* JAMES CROLL, *Glasgow.*

From the fact that those gases which are most easily liquefied by compression are those which are found to deviate most from the law of Mariotte, we are led to the conclusion that their deviations from this law are due to the mutual attraction of their particles. Deviations from Mariotte's law after the manner of carbonic acid follow as necessary consequences from cohesion. Other phenomena are also explainable on the same principle; such, for instance, as why the coefficient of expansion is greatest for the gases which deviate most from Mariotte's law—why the coefficient of expansion increases with the density in gases which deviate from this law—why, when equal weights are employed to compress different gases under the same conditions, the greatest amount of work is performed on the gas which deviates most—why, in the expansion of gases by heat, least work is performed by heating the gases which present the greatest deviation.

The influence of Cohesion in relation to the Experiments of Prof. W. Thomson *and* Dr. Joule *on the Thermal effects of Elastic Fluids in Motion.*

In these experiments, air, carbonic acid, or hydrogen, under very high pressure, was made to expand by forcing itself through a porous plug, and it was found that the temperature of the gas after expansion was somewhat less than before it; in other terms, the heat of friction was found to fall short of compensating the cold of expansion. The expenditure of elastic force experienced by the gas, in forcing itself through the porous plug, tends in the first instance to lower its temperature; but as this force is spent in friction, the heat produced from friction ought exactly to compensate the cold of expansion. This is only the case, however, when *all* the force of expansion has been spent in friction; if a portion of this force be consumed in producing some other effect than heat, then the heat of friction will not compensate the cold produced by the waste of force in expansion, and a cooling effect will be the result. Now it is perfectly evident that if the atoms of a gas when compressed attract each other, the force of expansion cannot be all converted into heat, a portion of it must be consumed in overcoming attraction, hence the heat of friction will fall short of compensating the cold of expansion by an amount equal to the equivalent of the work against attraction.

It is generally understood that in certain cases a heating instead of a cooling effect may take place. How this may occur is not so apparent. Prof. W. Thomson states, that when the temperature of air rises above a certain height, the heat of friction will exceed the cold of expansion, because $P'V'$, the work which a pound of air must do in expanding through the plug, is rather less than PV, which is the work done on it in pushing it through the spiral up to the plug. It is by no means obvious how this can result in a heating effect. That which produces the cold of expansion is the expenditure of the elastic force in expanding through the plug; but as this force is not consumed on external work, but entirely spent in friction on the particles of the air itself, the force which it loses on the one hand is entirely restored to it on the other. But more force cannot be restored than was lost; for the force restored is just what was lost.

The only way whereby it is possible to account for a heating effect, is by supposing that a gas which exhibits the heating effect possesses a certain amount of elasticity independent of heat, and that the expenditure of this force in the production of heat by friction, is an expenditure of elastic force, but not an expenditure of heat—a conclusion which is very improbable.

The Influence of Cohesion in relation to Carnot's *Function.*

The following was suggested by Dr. Joule, in a letter to Prof. W. Thomson in 1848, as the true expression of Carnot's function,

$$\mu = J.\frac{E}{1+Et},$$

J denoting Joule's equivalent, E the coefficient of expansion[*], and t the temperature in Centigrade degrees, measured from the temperature of melting ice. Prof. W. Thomson has been led, from calculations based upon Regnault's observations on the pressure and latent heat of steam, to the conclusion that μ cannot in all cases be expressed by the above formula.

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[*] In this formula Carnot's function is equal to the mechanical equivalent of the thermal

May not the deviations, however, be entirely due to the influence of cohesion? It is evident that cohesion must affect the value of this function in the following manner: if a mutual attraction exist between the particles of a gas at a given temperature, then that gas in cooling itself down one degree below that temperature, by performing mechanical work in expanding, will execute less work than it would otherwise do did no cohesion between the particles exist; for a portion of the heat must be consumed in work against the cohesion. The quantity consumed by cohesion will continually increase as the temperature diminishes; for as the temperature diminishes the cohesion increases. But in regard to steam and all other saturated vapours, the reverse holds true, for the cohesion of the particles of vapours increases as their temperature rises, because their density increases with rise of temperature. In the case of a perfect gas, the function will agree with the formula at all temperatures; but in imperfect gases and vapours the function will deviate from the formula, but in opposite directions. In both cases the actual function will fall short of the theoretical.

On the Supernumerary Bows in the Rainbow. By the Rev. J. DINGLE.

The author gave a method of approximating to the size of the drops of rain corresponding to any given position of the supernumerary bows produced by the interference of the two luminiferous surfaces proceeding from each drop. It appeared from his tables appended to the paper that the size which Dr. Young (without giving his method of calculation) had assigned to the drops under certain conditions was within $\frac{1}{2000}$th of an inch of the truth, and was more accurate than that assigned subsequently by Mr. Potter.

On the Duration of Fluorescence. By Dr. ESSELBACH.

The author described the apparatus by which he succeeded in 1856 in proving the duration of fluorescence ($\frac{1}{2000}$ second with uranium glass), thereby establishing a year before M. Becquerel the experimental link between this interesting phenomenon and phosphorescence.

Description of an Optical Instrument which indicates the Relative Change of Position of Two Objects (such as Ships at Sea during Night) which are maintaining Independent Courses. By J. M. MENZIES.

This instrument consisted of a lantern-shaped case, containing a lens in front and a concentric sheet of bent glass behind, at the focal distance of the lens, ruled with parallel vertical lines. This was hung up on gimbals so as to have its axis parallel to the course of the vessel, and the bright spot (the image of the light of the approaching vessel) showed by its position and shifting the relative place and course of the approaching vessel.

Experiments on Photography with Colour. By the Rev. J. B. READE, *F.R.S.*

A recent examination of the phenomena of polarized light in their immediate connexion with the undulatory theory led the author to inquire into the causes of natural colours, and thence to the possibility of coloured objects setting up, in sensitive films on which their image is thrown, the very same causes which regulate and determine their own respective colours. This being effected, the image of an object would communicate to the eye the identical colour of the object itself.

The propositions, in general terms, are—that radiant-coloured light consists in undulations of the luminiferous ether—that all material bodies have an attraction for the ethereal medium, by means of which it is accumulated within their substance

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unit, divided by the absolute temperature. The reciprocal of E must be the absolute temperature of melting ice, or the formula is erroneous.

and exerts its influence beyond them—and that the luminous phenomena are exhibited under two modifications, the vibratory or permanent, and the undulatory or transient state. This theory leads to the conclusion that the undulations within the substance of material bodies communicate their vibrations to the ethereal medium without them, and thence to the same medium within the eye. If the undulations be such as to produce red, red is seen by the eye, and so for other colours. Now, as we have films eminently sensitive to the action of reflected light, and capable occasionally of being coloured by such light, it is clearly within the laws of physical science to suppose that the several portions of the excited film may retain within themselves, in the vibratory and permanent state, the varying undulations of the coloured objects whose images they receive. A picture with the colours as in nature would be the result, instead of the mere black and white mezzotint at present obtained. The desiderata are—a sensitive silver compound capable of receiving and transmitting the undulations, and energetic reflexions from the objects themselves.

Shortly before the meeting he happened to obtain unusual traces of colour in photographic portraits. The chief difference in manipulation was a slight excess of the iodizer in the collodion, and the addition of acetic acid and acetate of soda to the bath. And in order more fully to test the effect of the cadmium and bromo-iodizers, he increased the quantity until natural colours ceased to be strengthened. The final proportion of iodizing solutions gave the portrait which was exhibited. The general warm colours of the forehead and face, and the tone of the coat were fairly represented in the portrait.

Remarks on the Complementary Spectrum. By J. Smith.

The author endeavoured to explain, on the principle adopted by him in his chromatrope experiments, the well-known fact that the spectrum of a hole in the window-shutter, when received on a screen, has the violet end above and the red below, but when looked at through the prism, the red appears above and the violet below.

On the Motion of Camphor, &c. towards the Light.
By Charles Tomlinson, *King's College, London.*

Books on chemistry from the time of Chaptal (1788) to the present, recognize the fact that salts in crystallizing move towards the light; that camphor, water, alcohol, &c. form deposits on the most illuminated side of the bottles that contain them. The history of the subject includes the names of Petit, Chaptal, Dorthes, Draper, &c. Chaptal's experiments were made with saline solutions, and he found that crystalline deposits could be determined to any point by admitting the light to that point, or prevented by shutting out the light. Dr. Draper, who named these phenomena *perihelion* motions, found that in the case of camphor deposits were sometimes made nearest the sun, and at other times furthest from him, the latter being termed *aphelion* motions; that reflected light and coloured light produced aphelion movements; that the deposits are not produced in the dark, or by artificial light, and that rings and disks of tinfoil prevent the formation of deposits. He supposed electricity to be concerned in the production of these phenomena.

Mr. Tomlinson shows that neither light nor electricity has anything to do with these effects, but that they are the simple results of cooling. By treating the vapour of camphor, &c. as dew, all the effects follow; and Chaptal's results are obtained in full sunshine without any shutting out of the light, but simply by preventing radiation by means of transparent screens. When a bottle containing camphor, &c. is exposed to light, the illuminated side is generally the colder, and hence the deposit on this side; but when the sun is shining on the bottle, the furthest side is the colder, and there the deposit takes place. Bottles of camphor kept in the dark, *i. e.* in a cupboard or drawer, are equally warm all round, and hence no deposit is formed; but if such a bottle be cooled on one side by means of a piece of filtering-paper dipped in ether, a deposit is instantly formed. If a bottle of camphor be plunged into water at 100° no deposit is formed, because it is equally hot all round. If a number of bottles be covered with opake substances and exposed to the sun, or to a heated cannon-ball, deposits are formed or not according as the screens absorb or reflect heat: a screen of tinfoil will not allow a deposit to be formed; but if the screen be of brown paper, there will be an abundant furthest deposit. So also if a bottle have attached to it disks and rings of tinfoil, paper of various colours, &c., no deposit will be formed in and about such disks, because they keep the bottle warm by preventing radiation, and even by absorbing heat. A disk of black paper put on a deposit already formed will clear away a much larger space than tinfoil will do.

The author found that crude camphor was more sensitive in its action than refined; but that the experiments succeed with ordinary camphor, Borneo camphor, artificial turpentine camphor, camphoric acid, iodine, naphthaline, chloral, water, alcohol, ether, &c.

Electricity, Magnetism.

On the Mechanical Power of Electro-Magnetism, with special reference to the Theory of Dr. Joule *and* Dr. Scoresby. *By* James Croll, *Glasgow.*

In an article by Dr. Joule and Dr. Scoresby on the mechanical power of Electro-magnetism*, it is stated that when the electro-magnetic engine is set in motion and the current in consequence reduced from a to b, the heat manifested in the circuit is reduced from a^2 to b^2, but the heat which is produced by the oxidation of the zinc is only reduced from a to b; hence they conclude that the quantity of heat equal $a-b$ produced by the zinc plates, but which does not appear in the circuit, is consumed in the production of mechanical effects. That this conclusion is not satisfactory will appear, the author thinks, from the following considerations, viz. if we reduce the current from a to b by merely reducing the consumption of the zinc from a to b, the heat evolved in the circuit will in this case also be reduced from a^2 to b^2. The question now arises, what becomes of the amount of force $a-b$ which disappears in the circuit here also? It is not consumed in work, for no mechanical effect takes place. Hence, from the disappearance of heat when the electro-magnetic machine is set in motion, we are not warranted to conclude that it went to produce mechanical effects; for it equally disappears in the other case when no mechanical effect is produced. The true explanation of the matter, he thinks, is this: when we reduce the current from a to b, we reduce the heat evolved in the conducting wire from a^2 to b^2, but we only reduce the heat evolved in the entire circuit from a to b; hence there is no disappearance of heat whatever. The simple fact is, the heat which is missing in the conductor will be found in the battery; however, when the engine is in motion there will be a deficiency in the total heat evolved equal to the thermal equivalent of the mechanical work performed. When the engine being at rest the current is equal b, the total heat evolved is also equal b; but when the current is reduced to b by the motion of the machine, the total heat evolved will then be equal $b-x$; x being the equivalent of the mechanical work performed. The value of x, therefore, is not determined by the theory of Dr. Joule and Dr. Scoresby.

Let us consider the theory in relation to the origin of the mechanical work. When the current is equal b, without mechanical work being performed, the heat evolved in the conductor is b^2; when the current is b, and mechanical work performed, according to the theory the heat evolved in the conductor is also equal b^2. In this case there is no reduction of heat in the conductor corresponding to the mechanical effect produced; for the heat is as great when the mechanical effect takes place as when it does not, being in both cases equal b^2. This would lead to the conclusion that the mechanical effect is not derived from the current b, for it could not possibly produce its full equivalent of work, in the shape of heat b^2 and x amount of work in addition. The work x must, therefore, according to this theory, be derived directly either from the chemical action in the battery or from the heat evolved. That it is not directly dependent upon chemical action is evident from the fact that, if the current exist, x will arise the same as before, whether there be chemical action or not, as, for example, when the current has a thermal origin; and that it is not derived from the heat evolved is evident also from the fact that it has no existence when the heat is present in the circuit without the current. The mechanical work is therefore, contrary to the above theory, derived directly from the electric current; and it follows from hence that when we have two currents equal in every respect, the one performing mechanical work and the other producing nothing but heat, less heat must be evolved by the former current than by the latter; consequently the law involved in the theory, viz. that the heat evolved in similar conductors is proportional to the square of the currents, does not hold true when one of the currents produces magnetical effects.

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* Philosophical Magazine, June 1846.

Facts seem to lead to the following theory as a true explanation of the mechanical power of electro-magnetism. Whatever our views may be regarding the nature of the electric current, we must allow that the molecules of bodies offer a certain amount of resistance to the passage of the current, which amount differs according to the nature of the body through which the electricity is propagated. It must also be admitted that the molecules of the body, in consequence of the resistance which they offer, become heated. Let us take now the case of the conducting wire connecting the pole of a battery. Suppose it to be composed of a succession of molecules A, B, C, D, &c. The chemical action in the battery communicates a certain amount of motion to the atom A, in consequence of which its equilibrium is destroyed, and to regain this state it transmits motion to the next adjoining atom B; but B offers resistance to A, and the consequence is that A is unable to communicate to it the full amount of motion necessary to restore its own equilibrium, so that A must still retain a portion of the disturbing force or motion received from the battery; but on account of its position in space being limited by its relations to surrounding molecules, it can only retain motion or force in itself by vibrating, and in virtue of these vibrations we affirm it to be hot. B in like manner, to regain its equilibrium, transmits motion to C, but C likewise offers resistance to B, and, of course, B must also retain a portion of the disturbing force in the form of heat, and what holds true of A, B, and C, holds equally true in regard to all the other molecules of the conductor.

Let us now observe what takes place when work is being performed by an electro-magnetic engine. We have, in the first place, a continual evolution of force arising from chemical action in the battery. This chemical force becomes immediately transformed into electric current, and the electric force must in turn be constantly transformed into some other form of force, or else we should instantly have an accumulation of current. When the current is allowed simply to circulate in the conductor without producing any work, either chemical or magnetical, its entire force is transformed into heat, and the heat in turn is transmitted to surrounding objects and radiated into space. This, as we have shown, is the effect of forces tending to a state of equilibrium. When the soft iron of the electro-magnetic engine is brought into the presence of the conductor, another channel or outlet is then offered to the molecules of the conductor, whereby they may get rid of the disturbing force, the electric current; a portion of this force will be transferred to the molecules of the iron, causing them to assume the magnetic state, and, of course, whatever is consumed in work upon the molecules of the iron cannot appear in the molecules of the conductor in the shape of heat. The moment the molecules of the iron assume the magnetic state, no further transference of force in this direction can take place; but if they are allowed to perform mechanical work while they are assuming this state, as is the case when the electro-magnetic engine is in motion, then a constant outlet is afforded in this direction to the disturbed molecules of the conductor to regain their equilibrium. But it must be observed that the relative proportions of the force which pass through each of the two channels or outlets, heat and magnetical work, do not remain the same, as Dr. Joule and Dr. Scoresby's theory implies; for as the force will always tend to the path of least resistance, the relative proportion passing through each outlet will be determined by the relative resistance offered—the quantity passing through each being inversely as the resistance to be overcome. Now the quantity x of mechanical work that can be produced by an electro-magnetic engine from a given quantity of electric current, *will depend entirely upon the amount of resistance offered by the magnetic element as an outlet to the electric force.* If the iron is hard, and the resistance consequently great, the amount of work will be but small; but if the iron is soft and the resistance offered small, then the amount of force transformed into magnetism and available for mechanical purposes will be greater.

In a paper read before the Chemical Society in March last, the author showed that the same principle holds true also in regard to heat. When heat is applied to a solid or a liquid body, a portion of the heat goes to raise its temperature, and another portion is consumed in internal molecular work against cohesion. The rising of the temperature and the separation of the molecules are the two paths or outlets for the force, and the relative proportion which passes through each is determined here in like manner by the resistance offered by each to the passage of the force. Hence the reason why the specific heat of bodies increases as their temperature rises; for the resistance offered by cohesion decreases with rise of temperature, thus allowing a greater proportion of the heat applied to become latent in internal molecular work. It was stated as a general principle *that, other things being equal, the more easily fused a body is the greater is its specific heat.* This was shown also experimentally to be the case.

In conclusion, in the production of molecular work by heat or mechanical work by means of electro-magnetism, there exists no fixed relation between the amount of heat applied and the work performed, for in both cases the quantity of work varies with the molecular resistance offered.

On Electric Cables, with reference to Observations on the Malta-Alexandria Telegraph. By Dr. ERNEST ESSELBACH.

The three sections of this cable touching the shore at Tripoli and Benghazi represent three condensers of 75,000 to 150,000 feet square, which, on account of their size, disclosed several important facts in regard to the nature of the dielectric. They allowed, in the first instance, a clear separation of the residual charge from the resistance test. Dr. Esselbach arrived thereby not only at the true resistance of gutta percha, but attained a new and entirely different test for insulation (electrification test), by which the absence of electrolytic action in the covering could be distinctly ascertained. These observations further afforded proof that the residual charge on Leyden jars was not a penetration of electricity like that of heat in a metal, but an increase of the specific inductive capacity of the material, and merely a function of time, analogous to certain corresponding phenomena of torsion and magnetism. The absolute quantity of charge, as ascertained in Dr. Esselbach's previous paper, showed that an increase in inductive capacity of one per cent., under the influence of electric tension, was sufficient to account for what appeared to the galvanometer as a change in resistance amounting sometimes to as much as 50 per cent.

Dr. Esselbach further showed his diagrams on earth-currents, extending over one month's observation, indicating the great advantage which two lines of 500 and 600 miles from east to west, and one from north to south, in one continuation, offer, and the facility and precision with which they are observed by Wheatstone's bridge.

The cable is taken roughly as being 2000 times better than the old Atlantic cable; and whereas in this latter at least 80 per cent. of the strength of current was lost in the transit, more than 99 per cent. actually arrives in the present case at the other end. The speed of a signal through this cable has been ascertained in different ways, and in the most perfect way by Captain Spratt, C.B., incidentally, upon a comparison between the longitude of Malta and Alexandria. The time for one signal through the whole length of 1300 miles approaches one second nearly. The author drew attention to the fact that the question of practical speed, after having first been brought into prominence by Mr. Latimer Clark's experiments, had remained in abeyance since Professor Thomson's researches at the time of the laying of the Atlantic cable, after which all interest had been absorbed by the insulation question, and very rightly, since it was first necessary to establish communication, and with certainty, before trying to precipitate it. This appearing now assured by a great and deserved success of manufacturers, attention could freely be turned to experiments on speed, as entered upon by Messrs. Jenkin and Varley; and he mentioned that applications had been made to Government from the first authorities to take advantage of the Malta-Alexandria Telegraph for the purpose.

On an Experimental Determination of the Absolute Quantity of Electric Charge on Condensers. *By* Dr. Esselbach.

This quantity having first been approximately ascertained by Faraday, had been afterwards established by the researches of Weber, Thomson, and Joule; but the application of these results to submarine cables requiring intermediate reductions, the author undertook a direct determination, for which the means had since become available.

A cable of certain description was charged (and discharged) by 100 Daniell's 400,000 times in $14^h\ 30'$; this quantity of electricity deposited in four several voltameters 12·9 mgr. of silver. The determination was repeated under different conditions. The absolute quantity can hence be calculated for any other cable by means of the well-known formula for determining their relative capacities. The quantity of charge on the whole Malta-Alexandria cable by 20 cells (the ordinary speaking power) is accordingly equivalent to 0·013 mgr. of silver, a quantity which is furnished in 0·964 second by the battery in a closed circuit of 2500 units (one Daniell by 1000 mercury units depositing 4·01 mgr. of silver per hour). This would therefore be the maximum speed with this battery, as far as merely the quantity of electricity is concerned. During the investigation of the method which preceded the experiment, Dr. Esselbach found the charge and discharge influenced by the resistance to sufficient extent to admit of verifying experimentally the second case of Professor Thomson's theory of discharge, which is of practical importance for the question of velocity.

Account of an Electromotive Engine. *By* G. M. Guy.

The author explained the difficulty of obtaining, by any of the methods heretofore suggested, a sufficiently rapid motion within the small spaces through which magnets or electro-magnets acted with sufficient energy, and chiefly in consequence of the rapid diminution of that energy as the distance of the poles increased, even by very minute quantities. He exhibited and explained to the Section a working model of the engine.

METEOROLOGY.

Suggestions on Balloon Navigation. *By* Isaac Ashe, *M.B.*

The author proposed a simple contrivance by means of which the opening of the escape-valve should depend, when desirable, on the relaxation of voluntary exertion on the part of the aëronaut, so that in the event of insensibility supervening at great altitudes, the valve should open spontaneously by means of a weight attached to its rope, thus causing a descent of the balloon to safer altitudes, and obviating the danger to life incurred by Messrs. Glaisher and Coxwell during their recent scientific ascent from Wolverhampton in consequence of their becoming insensible.

Dr. Ashe also proposed the adaptation of screw propulsion to balloons, suggesting a very light screw, capable of being elevated and depressed through an angle of about 150°, so as to be capable of being hoisted while the balloon should be on the ground, of being used horizontally as a propeller, or vertically underneath the car to cause a temporary ascent, as for the purpose of crossing a mountain-range without loss of ballast, which would involve remaining at the elevation so gained, or, on the other hand, by reversing the action of the screw, to effect a descent without loss of gas. Such a screw he considered could be worked at small elevations (2000 feet) by the exertions of the aëronaut; and its advantages would consist in the conferring, to a certain degree, of definite direction, and also of steering-power, and in obviating the objection to hydrogen balloons, which consisted in the expense of this gas, as a descent could be effected without loss of gas; hence smaller and much more manageable balloons might be constructed than those now in use, and propulsion by means of a screw would be so much easier.

Steering-power being obtained, Dr. Ashe hoped that a modification of shape might be found practicable, so as to present a minimum of resistance to propulsion by the screw. He proposed to steer by means of two small screws connected by a cranked axle placed at right angles to the action of the propeller, and situated in front of the car, so as not to interfere with the hoisting of the propeller; these steering-screws should have their spirals turned in the same direction, and by revolving them in one direction, or the reverse, the balloon might be made to rotate on its vertical axis as might be desirable. The disagreeable rotation incident to balloons might also thus be obviated. Dr. Ashe suggested the employment of balloons in the investigation of aërial currents and circular storms, and for the exploration of unknown continents: water, that great desideratum in such explorations, could be observed from an elevation when it would otherwise be passed by unobserved, and a descent being effected by the screw, its position might then be taken by observation, and marked for the guidance of foot explorers. Similar remarks would apply to the discovery of the easiest routes by means of balloon observations.

On some Improvements in the Barometer. By Isaac Ashe, *M.B.*

The author suggested a contrivance by which a water-barometer might be constructed, having a tube of not more than $3\frac{1}{2}$ feet in length, with a range in the height of the column of liquid equal to about 39 inches. Though correct in theory, this contrivance seemed to have some defects which would practically interfere with its accuracy.

On the Determination of Heights by means of the Barometer. By John Ball.

The object of this paper was to direct attention to the serious errors which are involved in the ordinary process of reducing barometric observations taken for hypsometrical purposes. This process involves two assumptions: 1st, that the volume of a column of air unequally heated is nearly the same as that of an equal weight of air of the same mean temperature; 2ndly, that the mean temperature of the column or stratum of air between the stations of observation corresponds to the mean of the readings of thermometers standing in the shade at each station. The error involved in the first assumption is not very considerable; that arising from the second is, on the contrary, highly important.

M. Bravais, who along with M. Charles Martins has contributed largely to our knowledge of the meteorology of the Alps, was the first to propose a practical plan for applying a correction to the assumed mean temperature of the air depending upon the hour of the day and the season of the year at which observations are made, but it is to M. Plantamour, the distinguished astronomer of Geneva, that we owe the fullest investigation of this important subject.

Having ascertained by careful levelling the true height of the Great St. Bernard above Geneva, M. Plantamour finds that the mean of all the barometric observations, made during eighteen years, deviates by fourteen English feet from the true height, and he attributes this deviation, with great apparent probability, to an abnormal depression of the mean temperature of Geneva, owing to the neighbourhood of the lake.

The readings of the barometer and thermometer at the observatories of Geneva and the St. Bernard are taken daily at nine hours or epochs. M. Plantamour assumes that, on an average of a long period of years, the mean of the observations taken at any one epoch in the twenty-four hours should give the true difference of height between the two stations, with an error due to the difference between the mean of the readings of the thermometers at both stations at the same epoch, and the true mean temperature of the air in the intervening stratum. Calculating then the height of the St. Bernard by the elements corresponding to each epoch of the day during the four summer months, from June to September, he obtains a series of measures differing from the true height—those corresponding to the hottest hours being in excess, and those appertaining to the coldest hours in defect of the true height. He then ascertains the amount of correction which, being applied to the mean sum of the readings of the thermometer at each epoch in each of those months, would bring out the true height. In this manner he obtains a table, showing what he calls the normal correction for each of the nine epochs of the day during the four summer months. There is good reason to believe that, in reducing barometric observations which are to be compared with Geneva and the St. Bernard, the application of the normal correction ascertained in the manner above stated will in general give truer results than those where this is not applied; but as it is obvious that the conditions of temperature at the moment when a given observation is made are constantly varying from the mean of the corresponding day and hour, it follows that a further supplemental correction should be made on this account.

To apply this further correction is a matter of no slight difficulty. The method employed by M. Plantamour is as follows. He obtains from the observations at Geneva and the St. Bernard (by interpolation when necessary) the elements corresponding to the day and hour of the observation which is sought to be reduced, and from these he calculates the height of the St. Bernard. The height so obtained, when compared with the measure which is derived from the mean of the readings for the same day and hour, as shown in his Table of normal corrections, furnishes a criterion by which to judge of the conditions with respect to temperature of the moment when the observations to be reduced were made. M. Plantamour thinks it not difficult to infer from the observations themselves, and from the general state of the weather at the time, whether the moment was one of atmospheric equilibrium or the reverse. In the latter case the observation is treated as one of inferior utility, to which a lower value should be assigned in the final calculation. Supposing, on the contrary, the observations not to betray a disturbance of equilibrium between the two stations, the deviation of the height, as calculated for that particular moment from the height derived from the corresponding means, is the measure of the amount and sign of the supplemental correction corresponding to the moment of observation.

Without entering at present into sundry points of secondary importance, the writer believes that, while it is at present impossible to clear the mode of dealing with this correction of some arbitrary elements, it is easy to adopt a system less cumbrous and less inconvenient, and at least equally accurate with that proposed by M. Plantamour. He finds that many of the observations which appear to M. Plantamour to be clear of anomalies arising from the disturbance of atmospheric equilibrium, show unequivocal traces of such disturbance. These anomalies can be eliminated only by comparing the observations in hand with many different standard stations, such as Milan, Turin, &c.; but, in the absence of direct evidence, the introduction of an empirical correction in the manner proposed is likely to lead to error.

The writer proposes to deal directly with the correction for temperature upon the best information that is available in regard to each of the stations where observations are recorded. He considers that the deviation of the thermometer at the time of observation from its mean height at the corresponding day and hour, is a tolerably accurate measure of its greater or less deviation at that time from the true temperature of the air freed from surface-radiation, and may therefore be taken with its proper sign for the supplemental correction.

It is important that the comparison between Geneva and St. Bernard, made by M. Plantamour, should be extended to other stations near the base of the Alps, and for this, as well as other reasons, it is highly desirable that the observations at Milan and Turin should be made at hours which correspond with the Swiss observations.

On the Extent of the Earth's Atmosphere.

By the Rev. Professor Challis, *M.A., F.R.S., F.R.A.S.*

The object of this paper was to show that the earth's atmosphere is of limited extent, and reasons were adduced, in the absence of data for calculating the exact height, for concluding that it does not extend to the moon. It was argued on the hypothesis of the atomic constitution of bodies, that the upward resultant of the molecular forces on any atom, since it decreases as the height increases, must eventually become just equal to the force of gravity, and that beyond the height at which this equality is satisfied, there can be no more atoms, the atmosphere terminating with a small finite density. It has been generally supposed that the earth's atmosphere is about 70 miles high, but on no definite grounds, and the estimates of the height have been very various. Against the opinion that it extends as far as the moon, it was argued that, as the moon would in that case attach to itself a considerable portion by its gravitation, which would necessarily have some connexion with the rest, there would be a continual *drag* on the portion more immediately surrounding the earth, and intermediately on the earth itself, which would in some degree retard the rotation on its axis. Hence if, as there is reason to suppose, the rotation be strictly uniform, the earth's atmosphere cannot extend to the moon. The author also stated that if by balloon ascents the barometer and thermometer were observed at two heights ascertained by observation, one considerably above the other, and both above the region in which the currents from the equator influence the temperature, data would be furnished by which an approximate determination of the height of the atmosphere might be attempted.

On the "Boussole Burnier," a new French Pocket Instrument for measuring Vertical and Horizontal Angles. *By* F. GALTON, *F.R.S., F.R.G.S.*

This instrument is about 3 inches long and ¾ inch deep. Its outside is composed of two faces of brass with pear-shaped outlines, separated by vertical sides. In the body of the instrument are two delicate circles placed in parallel planes; at its smaller end is a cylindrical lens, which views the nearer graduations on the rims of the two circles; on the upper face of the instrument are sight-vanes like those of an azimuth compass; on the lower face is a light universal joint, which is used when the instrument is attached to a support, and not held, as it may be, in the hand.

One of the circles is of aluminium, and is borne by a compass-needle; it gives horizontal angles when the instrument is held horizontally. The other is of silvered copper, unequally weighted, and is supported by a delicate axis playing in jewelled holes: it gives vertical circles through the action of gravity when the instrument is held vertically, just as the compass-circle gives azimuthal angles through the action of the magnetic force when the instrument is held horizontally.

The remarkable simplicity and compactness of the Boussole Burnier would make it useful to the traveller, the geologist, and the military engineer. It is the invention of Lieut.-Col. Burnier of the French Engineers, and has been perfected in its details by M. Balbreck, No. 81 Boulevard Mt. Parnasse, Paris.

European Weather-Charts for December 1861. *By* F. GALTON, *F.R.S., F.R.G.S.*

The author submitted for examination a series of printed and stereotyped charts, compiled by himself, that contained the usual meteorological observations made at eighty stations in Europe, on the morning, afternoon, and evening of each day of December 1861. They were printed partly in symbols and partly in figures, in such a form that each separate group of observations occupies a small label, whose centre coincides with the geographical position of the station where the observations were made. The amount of cloud is expressed by shaded types, the direction of the wind by an equivalent to an arrow, and its force by a symbolical mark. The temperature of the wet and dry thermometers, and the barometric readings (reduced to zero and sea-level) are given in figures. As the charts had been too recently printed to admit of a thorough examination, and as they were ultimately to appear as a separate publication, the author abstained from other deductions than those that were obvious on inspection. Among these, the enormous range and the simultaneity of the wind-changes, testifying to the remarkable mobility of the air, were exceedingly conspicuous.

On the Distribution of Fog round the Coasts of the British Islands.
By Dr. GLADSTONE, *F.R.S.*

Certain conclusions on this subject formerly arrived at by the author had been re-examined by means of additional returns from the meteorological journals kept at all the stations belonging to the three general lighthouse authorities in England, Scotland, and Ireland, and some returns lent him by Mr. James Glaisher. These afforded confirmation of the greater uniformity of distribution of fogs over the surface of the sea than on land, of their great prevalency where the south-west wind from the ocean strikes upon high ground, of the comparative infrequency of fog on the coasts of straits or portions of sea nearly surrounded by land, and other points previously noted. The returns also indicated that some years are much more foggy than others in nearly all localities; that the same fog sometimes prevails over a large extent of country; and that the frequency of fog differs very greatly in different months of the year, January, February, or March being on some coasts almost free. A generally accepted means of distinguishing between "fog" and "mist" is a great desideratum.

On a New Barometer used in the last Balloon Ascents.
By J. GLAISHER, *F.R.S.*

Mr. Glaisher exhibited a mercurial barometer which had been designed and constructed by Messrs. Negretti and Zambra for the purpose of checking the readings of the Gay-Lussac's barometer which had been used in the several late balloon ascents. The correctness of the readings of a Gay-Lussac's barometer at low pressure depended upon the evenness of the tube, and it is difficult to calibrate so large a tube. Messrs. Negretti and Zambra selected a good tube, 6 feet in length, attaching a cistern to its lower end. Mercury was boiled throughout the length of the tube; at the entrance of the cistern was placed a stopcock, by which means any definite quantity of mercury could be allowed to pass from the upper half of the tube into the cistern, and its height in the cistern noted and engraved; then a second portion, and so on. This process could be repeated. When the cistern was thus satisfactorily divided, the tube was cut in two, and to the upper half the cistern was joined; a scale was attached to this portion, and the reverse operation was performed, viz., allowing portions of the mercury to pass from the cistern into the tube, which could be regulated by means of the stopcock, and thus the scale was divided. The process, in fact, is using the tube to graduate itself. In carriage, the stopcock locks the mercury in the tube. This instrument was used, and acted well on the extreme high ascent.

On the Additional Evidence of the Indirect Influence of the Moon over the Temperature of the Air, resulting from the Tabulation of Observations taken at Greenwich in 1861–62. *By* J. PARK HARRISON, *M.A.*

The author stated that the additional evidence derived from the observations of mean temperature at Greenwich for the years 1861–62 confirmed the conclusions arrived at from a tabulation of the observations for the forty-seven years previous, viz., that the temperature of the air at the moon's first quarter is higher than it is at full moon and last quarter, and that this is due to the amount of cloud at first quarter being greater on the average than it is at the periods of full moon and last quarter. The difference in the amount of rain also at first quarter in 1861–62 was 2·27 inches more than at full moon, on a mean of eighty-four observations on seven days at each period.

On the Relative Amount of Sunshine falling on the Torrid Zone of the Earth.
By Professor HENNESSY, *F.R.S.*

By the aid of the author's transformations of formulæ given by Poisson, the area of that portion of the equatorial regions of the earth which receives as much sunshine as the rest of the earth's surface is ascertained. This area, at the outer limits of the earth's atmosphere, is thus found to be bounded by parallels situate at distances of 23° 44′ 40″ at each side of the equator; hence the amount of sunshine falling on the outer limits of the earth's atmosphere between the tropics is very nearly equal to that which falls on the remaining portions of the earth's surface. If we reflect that, according to Principal Forbes's researches, the amount of heat extinguished by the atmosphere before a given solar ray reaches the earth is more than one-half for inclinations less than 25°, and that for inclinations of 5° only the twentieth part of the heat reaches the ground, we immediately see that the torrid zone of the earth must be far more effective than all the rest of the earth's surface as a recipient of solar heat. It follows, therefore, that the distribution of the absorbing and radiating surfaces within the torrid zone must, upon the whole, exercise a predominating influence in modifying general terrestrial climate.

On the Hurricane near Newark of May 7th, 1862, *showing the force of the Hailstones and the violence of the Gale. By* E. J. Lowe, *F.R.A.S. &c.*

The hurricane about to be described was accompanied by a thunder-storm, which was more or less spread over the centre of England. On the previous evening there were violent thunder-storms, accompanied in various places with large hailstones and with *rose*-coloured lightning. The hurricane of the 7th of May was remarkable for its violence near Newark, and for the violence of the thunder-storm which occurred at the same time; it will long be remembered in the neighbourhood on account of the devastation that was caused, for the particularly striking *night-like* darkness, for the great size and curious forms of the hailstones, and on account of the magnificence of the colour of the lightning. At Highfield House the morning was sultry, with thunder about noon, and again continuously in S. and S.E. at three o'clock. At half-past two the temperature in shade had risen to 73°·6 with a west wind, but the clouds whirling round in all directions, a low current carried broken nimbi rapidly from west, whilst the storm-cloud was approaching in a S.S.E. current. At half-past four o'clock the temperature had fallen to 60° (a descent of 13°·6 in two hours), whilst the wind had risen to half a gale. The thunder, though distant, was frequent. The sky gradually became blacker and blacker, until at five o'clock it was darker than I had ever before seen it except during a total eclipse of the sun. A book with bold type could scarcely be read at a window, nor away from it could the hands of a watch be seen. This storm put on very much the appearance of a total eclipse; near objects had a yellow glare cast upon them, and the landscape was closed in on all sides at the distance of half a mile by a storm-cloud wall. Rain fell in torrents, but not in an ordinary manner; it was swept along the ground in clouds like smoke. Flashes of lightning also came in impulses, four or five following each other in rapid succession, succeeded by a brief pause, and then four or five more. The colour of the lightning was lovely beyond description, being an intense *bluish red*—almost *rose*. The wind now veered to the S.S.E., taking the storm's direction. The temperature had descended to 51° (a fall of more than 22½°), and the anemometer showed 9 lbs. pressure on the square foot. Severe as this storm was at Highfield House, it dwindled into insignificance when compared with its violence near Newark. It is scarcely possible to imagine any destruction more complete than that effected by this fearful storm. Fortunately its ravages were confined within narrow limits, being restricted to three miles in length and 150 yards in width, commencing at the village of Barnby; after proceeding a mile its violence considerably increased; before reaching Coddington it tore up the hedges that surrounded the fields and unroofed the farm buildings. At Balderton Lane it threw down farm buildings and uprooted enormous oak-trees; a quarter of a mile further it unroofed the house of Mr. James Thorp's head keeper, the hailstones breaking nearly all the windows, having in many instances been driven through the glass, cutting out smooth holes. The spout of this house, too heavy for one man to lift, was carried 100 yards, and a perfectly sound elm-tree, about 60 feet in height and 5 feet 10 inches in circumference (where broken off), was snapped asunder four feet from the ground, and the tree carried twenty-nine yards through the air. The wood of this tree was twisted to the very heart. Here a man was lifted off the ground and then carried twenty yards, being unable to save himself, finally lodging in a hedge. Thirty or forty yards from Mr. Thorp's house at Beaconfield the hurricane divided, leaving the house itself intact, and also the trees in its immediate

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neighbourhood, from S. round by E. to N., while on the W. side outbuildings were unroofed or destroyed, the large garden wall thrown down, and the fencing around the plantations broken off and carried into the fallen timber. A few yards beyond the house the gale reunited, and passing through a wood destroyed all the trees; it then proceeded across fields as far as Winthorpe, and here its fury became exhausted.

The gale rotated in the direction of W. to S., which was apparent from the twist of the wood of the snapped-off trees, and also from an avenue of chestnuts situated on the extreme eastern edge of the hurricane having all the torn-off boughs lying on the S. or storm-side, and being carried back beyond the level of the trees.

Proposed Measurement of the Temperatures of Active Volcanic Foci to the greatest attainable Depth, and of the Temperature, state of Saturation, and Velocity of Issue of the Steam and Vapours evolved. By ROBERT MALLET, *C.E., M.A., F.R.S.*

The author having circulated the following document amongst various Members of the British Association a short time prior to the Meeting and during same, enlarged upon the objects of his proposed experimental inquiry; and explained to Section A, in part, the methods he intended to employ.

Determination of Volcanic Temperatures.—It is a singular fact, and one scarcely creditable to the past investigation of volcanic phenomena, that up to this time no careful attempt has been made to determine, even approximately, the temperature of the heated or incandescent focus of any active volcano, even at the mouth of the crater, still less to depths lower down.

Much labour and time have been lavished upon analysation of the gases and solid products evolved, and upon other still more minute inquiries—more than was necessary, indeed, to obtain all the leading information as to the nature of vulcanicity (using that general term to express the train of forces and of events whence the supply of volcanic heat and energy is kept up) which such results are capable of yielding; but the most obvious of all physical data, viz. those referring to the actual temperature of volcanic foci at the greatest attainable depths, have been completely neglected by vulcanologists, either because they too hastily concluded that experimental measurements of such were impossible, or, more probably, because, as often happens in the investigation of nature, the most obvious question is that which is longest neglected being put to nature.

The experiments that have been made on the heat of lava-*fissures*, and upon the temperatures of geysers, hot-springs, mines, &c., do not of course bear upon those here in point.

It seems almost unnecessary to dilate upon the importance to vulcanology, and to all cosmical physics, of some precise information as to these focal temperatures, the knowledge of which would assign limits at once to many speculations at present vague and perhaps valueless, give measure to the estimation of the forces concerned, and direct further investigation as to the sources whence these may be derived.

For brevity, the writer may venture to quote on this subject the following passage from his Report to the Royal Society on the great Neapolitan earthquake of 1857:—

"I cannot find that any professed investigator of volcanos has ever thought of making the very obvious and important experiment of lowering, with an iron wire, a pyrometer as far as possible into a crater, in order to get some idea of its actual temperature, even within a few score yards of its mouth.

"When on Vesuvius, on the occasion of this Report, I feel satisfied that I could have so measured the temperature of the minor mouth—then in powerful action—to the depth of several hundred feet, had I possessed the instrumental means at hand. To this smaller mouth it was then possible, by wrapping the face in a wet cloth, to approach so near upon the hard and sharply-defined (though thin and dangerous) crust of lava through which it had broken, as to see its walls for quite 150 feet down, by estimation. They were glowing hot to the very lips, although constantly evolving a torrent of rushing steam with varying velocity. Accustomed as I have been by profession for years to judge of temperature in large furnaces by the eye, I estimated the temperature of this mouth, by the appearance of its heated walls, at the lowest visible depth; they were there of a pretty bright red, visible in bright winter sunlight overhead. I have no doubt then that the temperature of the shaft at from 300 to 500 feet down was sufficient to melt copper, or from 1900° to 2000° Fahr.

"From the extremely bad conducting power of the walls of a volcanic shaft, there is scarcely any loss of heat from any cause, except its enormous absorption in the latent heat, of the prodigious volume of *dry steam*, which is constantly being evolved. It is *perfectly transparent* for several yards above the orifice of the shaft, and is not only perfectly *dry steam* but also *superheated*; and although this steam may be at the mouth very much below the highest temperature of the hottest point, the temperature of the shaft or duct that carries it off will be very nearly at all depths the same, to probably within a very short distance of the point of greatest incandescence."—Rep. Roy. Soc., &c., Pt. II. chap. xii. vol. ii. pp. 313, 314.

The writer respectfully urges that the organization of experiments to determine such data is a subject worthy the immediate attention of the British Association, the Royal Society, and other similar scientific bodies.

From recent information he has reason to believe that the existing state of Vesuvius is favourable to such experiments, which the writer is himself prepared to attempt, provided the necessary apparatus and other means be placed at his disposal. The experiments that he would in the first instance propose are—

(1) The temperature at the mouth or mouths, to the lowest reachable depths within the Vesuvian craters.

(2) The temperature of the issuing steam vapours or gases at the mouths, and the degree to which the former are superheated.

(3) Approximate determination of the velocity (extreme and mean) of the issuing discharge of steam, &c., with a view to estimation of the volume, in given time, and of the total heat carried off, in same.

For the 1st and 2nd, three or more mutually controlling methods may be employed. *a.* The air pyrometer, or that of Daniell, maximum self-registering. *b.* The differential bar pyrometer (of two metals), with constant galvanic connexion to the surface. *c.* The resistance coil thermoscope, also in constant connexion with the surface. The writer, as a practical engineer, has well-founded hope of inserting either or all of these to a considerable and known depth within the crater or craters.

For the 3rd, analogous methods should be employed. For the 4th, there is no doubt that Dr. Robinson's anemometer may be so modified as to be made available to determine the issuing velocity in various parts of the column. Into the mechanical arrangements for placing, lowering, and observing, &c. these instruments, it is not necessary here to enter.

Vesuvius presents many advantages as a first experimental station; but the inquiry would afterwards be advantageously extended to other volcanic vents. Whatever presumable difficulties may exist, if successfully overcome in the first case, will nearly vanish as regards subsequent repetitions elsewhere.

On Meteorology, with a Description of Meteorological Instruments.
By T. L. PLANT.

Meteorological Observations registered at Huggate, Yorkshire.
By the REV. T. RANKIN.

This notice was in continuation of those annually made for many years by the author on the Wolds of Yorkshire, at an elevation of 650 feet above the level of the sea. They contained the annual tables of means, with notes of the days on which the most remarkable events connected with the weather and meteors occurred during the year.

On Objections to the Cyclone Theory of Storms. *By* S. A. ROWELL.

Admitting that the winds in storms do at times take a more or less circular course, and that whirlwinds may sometimes occur during storms, the author believed that these are only occasional and minor phenomena in storms, and not the storm itself, as represented in the cyclone theory. He objected to the cyclone theory on the grounds that it is opposed to all the known natural laws which affect the condition of the atmosphere, as he believed it to be impossible that a disk of some hundreds of miles in diameter, but of a mere mile or so in thickness, of air lighter than the general atmosphere, could make its way for days and days in succession through the densest part of the atmosphere,—that the evidence in support of the theory is insufficient (this he attempted to show by the aid of diagrams from Reid's 'Law of Storms,' and a general reference to works of the kind), and that the phenomena of the (so-called) cyclone storms may be otherwise accounted for.

On the Performance, under trying circumstances, of a very small Aneroid Barometer. By G. J. Symons.

This instrument, which the author exhibited, had been worn constantly by him recently while at sea in rough weather, while riding and driving over roadless districts in the Orkneys, and also on several occasions when rough climbing and severe jumps had been necessary: he therefore presumed he might reasonably conclude that it had been fully tried. It had been tested before, during, and after the voyage, and had in each case given the same result when compared with mercurial standards. He therefore inferred that it might be considered even less liable to derangement from travel than an ordinary watch. The instrument was very small, being only two inches in diameter and three-quarters of an inch thick.

On the Disintegration of Stones exposed in Buildings and otherwise to Atmospheric Influence. By Professor James Thomson, *M.A., C.E.*

The author having first guarded against being understood as meaning to assign any one single cause for the disintegration of stones in general, gave reasons to show—1st. That there may frequently be observed cases of disintegration which are not referable to a softening or weakening of the stone by the dissolving away or the chemical alteration of portions of itself, but in which the crumbling is to be attributed to a disruptive force possessed by crystalline matter in solidifying itself in pores or cavities from liquid permeating the stone. 2nd. That in the cases in question the crumbling away of the stones, when not such as is caused by the freezing of water in pores, usually occurs in the greatest degree at places to which, by the joint agency of moisture and evaporation, saline substances existing in the stones are brought and left to crystallize. 3rd. That the solidification of crystalline matter in porous stones, whether that be ice formed by freezing from water, or crystals of salts formed from their solutions, usually produces disintegration—not, as is implied in the views commonly accepted on this subject, by expansion of the total volume of the liquid and crystals jointly, producing a fluid pressure in the pores—but, on the contrary, by a tendency of crystals to increase in size when in contact with a liquid tending to deposit the same crystalline substance in the solid state, even where, to do so, they must push out of their way the porous walls of the cavities in which they are contained, and even though it be from liquid permeating these walls that they receive the materials for their increase.

CHEMISTRY.

Address by Professor W. H. Miller, *M.A., F.R.S., President of the Section.*

Once in about a quarter of a century a mineralogist is placed in the chair of the Chemical Section of the British Association. This procedure is not without its inconvenience: many important questions are likely to present themselves during the meetings of the Section which a mineralogical president can rarely be competent to decide. In another point of view, however, this arrangement is more satisfactory;

it is symbolical of the removal of a barrier which once threatened to separate mineralogy from chemistry, to the serious detriment of both. While some mineralogists sought to exclude chemistry from their systems, chemists intent upon discovery in the newly opened field of organic chemistry neglected mineral analysis. But of late these mutually estranged sciences have exhibited a growing tendency to reunite, and to aid one another. The chemists now freely admit the mineralogists as their associates, not unfrequently sharing their labours, and include geometrical and optical characters in the descriptions of the new combinations they discover. Of this we have instances in the memoirs of Kopp, Rammelsberg, Hofmann, Sella, Marignac, Des Cloizeaux, and in those of Haidinger, Leydolt, Grailich, Dauber, Schabus, v. Lang, Schrauf, v. Zepharovich, Rotter, A. and E. Weiss, Murmann, and Handl. The experiments on the formation of minerals, commenced by Berthier and Mitscherlich, have since been varied in almost every possible way. Ebelmen, de Sénarmont (whose recent death is a grievous loss to the sciences we cultivate), Daubrée, Wöhler, Manross, and H. Deville have successfully imitated the processes of nature in producing a large number of crystallized minerals in the laboratory, and thus have helped to obliterate the boundary arbitrarily drawn between the studies of the chemist and those of the mineralogist.

The memoirs I have cited in proof of the intimate connexion of chemistry and mineralogy deserve our especial attention for another and more important reason. The observations they record, being made on crystals of accurately known composition, far exceeding the crystallized minerals in number, and differing from minerals in being quite free from any admixture of foreign matter, furnish the only data from which we may hope that some future Newton of the science will be enabled to discover a simple law of the dependence of the form, optical and physical properties of crystallized bodies on the substance of which they are composed.

On the Formation of Organo-Metallic Radicals by Substitution.

By George Bowdler Buckton, *F.R.S.*

The object of this inquiry was to investigate the order in which the metals of the organo-metallic radicals were capable of substitution, through the agency, in the first place, of simple metals, in the second place, of salts of simple metals, and in the third place, of salts of other organo-metallic bodies.

It was found that when metals acted upon these radicals, substitutions were affected, in the greater number of cases, in the order indicated by the ordinary electro-positive or electro-negative position of the contained metals. Exceptional cases, however, occurred.

By the action of sodium on mercuric ethyl, the mercury is partly extruded, and a double compound of mercuric and sodium-ethyl is obtained.

By the action of chloride of cadmium on zinc-ethyl, appreciable quantities of cadmium-ethyl were formed, which, however, could not be satisfactorily separated, either by distillation or the action of anhydrous solvents, from the unctuous mass of chloride of zinc which is one product observed.

Mercuric ethyl and bichloride of tin react powerfully with the evolution of much heat, and result in the separation of chloride of mercuric ethyl and chloride of stannic sesquiethyl, according to the equation

$$3\left\{\mathrm{Hg}\,\begin{matrix}\mathrm{Et}\\\mathrm{Et}\end{matrix}\right\}+\left\{\begin{matrix}\mathrm{Sn}\,\begin{matrix}\mathrm{Cl}\\\mathrm{Cl}\end{matrix}\\\mathrm{Sn}\,\begin{matrix}\mathrm{Cl}\\\mathrm{Cl}\end{matrix}\end{matrix}\right\}=3\left\{\mathrm{Hg}\,\begin{matrix}\mathrm{Et}\\\mathrm{Cl}\end{matrix}\right\}+\left\{\begin{matrix}\mathrm{Sn}\,\begin{matrix}\mathrm{Et}\\\mathrm{Et}\end{matrix}\\\mathrm{Sn}\,\begin{matrix}\mathrm{Et}\\\mathrm{Cl}\end{matrix}\end{matrix}\right\}.$$

Terchloride of antimony, on the other hand, is converted by mercuric ethyl into triethylstibene, the whole of the chlorine passing over to the mercuric radical.

$$3\left(\mathrm{Hg}\,\begin{matrix}\mathrm{Et}\\\mathrm{Et}\end{matrix}\right)+\left(\mathrm{Sb}\,\begin{matrix}\mathrm{Cl}\\\mathrm{Cl}\\\mathrm{Cl}\end{matrix}\right)=3\left(\mathrm{Hg}\,\begin{matrix}\mathrm{Et}\\\mathrm{Cl}\end{matrix}\right)+\left(\mathrm{Sb}\,\begin{matrix}\mathrm{Et}\\\mathrm{Et}\\\mathrm{Et}\end{matrix}\right).$$

From the circumstance that titanium, in many respects, imitates the behaviour of the metal tin in its combinations, experiments were made with the bichloride. Zinc-ethyl strongly reacts upon this body, if assisted by gentle heat. Chloride of

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zinc is formed, but gases are immediately disengaged if distillation is attempted. Bichloride of titanium and stannic diethyl result in the reduction of the bichloride to the condition of sesquichloride, whilst the oily chloride of stannic sesquiethyl separates according to the equation

$$\begin{array}{l}\mathrm{Sn}\begin{array}{l}\mathrm{Et}\\ \mathrm{Et}\end{array}\\ \mathrm{Sn}\begin{array}{l}\mathrm{Et}\\ \mathrm{Et}\end{array}\end{array}+2\left\{\begin{array}{l}\mathrm{Ti}\begin{array}{l}\mathrm{Cl}\\ \mathrm{Cl}\end{array}\\ \mathrm{Ti}\begin{array}{l}\mathrm{Cl}\\ \mathrm{Cl}\end{array}\end{array}\right.=2\left\{\begin{array}{l}\mathrm{Ti}\,\mathrm{Cl}\\ \quad\;\mathrm{Cl}\\ \mathrm{Ti}\,\mathrm{Cl}\end{array}\right.+\begin{array}{l}\mathrm{Sn}\begin{array}{l}\mathrm{Et}\\ \mathrm{Et}\end{array}\\ \mathrm{Sn}\begin{array}{l}\mathrm{Et}\\ \mathrm{Et}\end{array}\end{array}+C_4H_5Cl$$

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The paper concluded with considerations upon the possibility of substituting ethyl for oxygen in the organo-metals, and also remarked upon the question, possessed of considerable interest, how far, and in what manner, the introduction of different metals can be effected in the organo-metallic radicals, represented by the type

$$\begin{array}{l}\mathrm{R}\\ \\ \mathrm{R}\end{array}\left\{\begin{array}{l}\mathrm{X}+\\ \mathrm{X}+\\ \mathrm{X}+\\ \mathrm{X}+\end{array}\right.$$

Can RR be represented by different metals, in the same manner as X may represent different alcohol radicals? The author hoped shortly to be in a position to answer this inquiry.

On the Action of Nitric Acid upon Pyrophosphate of Magnesia.

By DUGALD CAMPBELL, *Analytical Chemist to the Brompton Hospital, London.*

When pyrophosphate of magnesia was dissolved in ordinary nitric acid, and exposed in an open capsule to temperatures ranging from 320° F. to 550° F. till the weight became constant for each temperature, it was invariably found to have increased very much in weight, although not always to the same extent, as shown below:—

Temperature.	Percentage increase of weight.			Difference.
320° F.	22	to	30	8 per cent.
420	19	to	21	2 ,,
550	13·5	to	14·5	1 ,,

When the pyrophosphate of magnesia, still retaining nitric acid, but constant in weight at 320° F., was heated sufficiently to drive off all the nitric acid, it was found to have decreased in weight, not to a uniform amount, but varying from 9 to 15 per cent., according to the greater or less rapid application of heat; on heating in the same manner the pyrophosphates of magnesia retaining nitric acid, and constant in weight at 430° F. and 550° F., they were found likewise to have decreased much in weight, although not to so great an extent, by pyrophosphate of magnesia being volatilized along with the nitric acid.

It is inferred from these experiments that nitric acid has a stronger affinity for magnesia than pyrophosphoric acid has, and that on adding nitric acid to pyrophosphate of magnesia, nitrate of magnesia is formed, pyrophosphoric acid being liberated; and this was proved to be the case by dissolving pyrophosphate of magnesia in nitric acid, evaporating the solution till syrupy, and then placing it under a bell-jar over sulphuric acid; after a time nitrate of magnesia crystallized, and pyrophosphoric acid could be drained off.

But although nitrate of magnesia is formed and pyrophosphoric acid set free on the addition of nitric acid to pyrophosphate, it is probable that, when this mixture is evaporated and heated, the products are not always mere mixtures of nitrate of magnesia and pyrophosphoric acid, but that they are sometimes compounds; and the reasons for this opinion are, that these products are but slightly deliquescent, that nitric acid is less readily expelled from them than from nitrate of magnesia, and that on heating these products suddenly, pyrophosphate of magnesia is volatilized, though it is not under ordinary circumstances a volatilizable salt.

From the above results, the author recommends the discontinuance of moistening the pyrophosphate with nitric acid when calcining it, when estimating phosphoric acid or magnesia, as it may be apt to lead to a source of error.

Mémoire sur les modifications temporaires et permanentes *que la chaleur apporte à quelques propriétés optiques de certains corps cristallisés. Par* A. Des Cloizeaux.

On sait, d'après d'anciennes recherches de MM. Brewster et Mitscherlich, que dans certains cristaux l'écartement des axes optiques et l'orientation de leur plan varient avec la température. Pendant longtemps on n'a guère connu que les phénomènes si tranchés qui se manifestent dans la Glaubérite et le gypse. J'ai constaté récemment qu'un assez grand nombre de substances anhydres ou hydratées, telles que le feldspath orthose, la Heulandite, la Prehnite, le clinochlore, la cymophane, la Brookite, &c., subissaient aussi l'influence de la chaleur d'une manière plus ou moins marquée; mais de plus j'ai découvert que si l'on élevait suffisamment la température, ce qu'il est facile de faire pour l'orthose, la cymophane et la Brookite, par exemple, les modifications optiques, de temporaires qu'elles sont lorsqu'on ne dépasse pas 300 à 400 degrés Centigrades, deviennent entièrement permanentes. Le minéral qui, par sa transparence et son homogénéité, se prête le mieux aux expériences les plus variées et les plus exactes, est un orthose vitreux de Wehr dans l'Eifel, et c'est sur une plaque de cette nature que j'ai obtenu les résultats suivants.

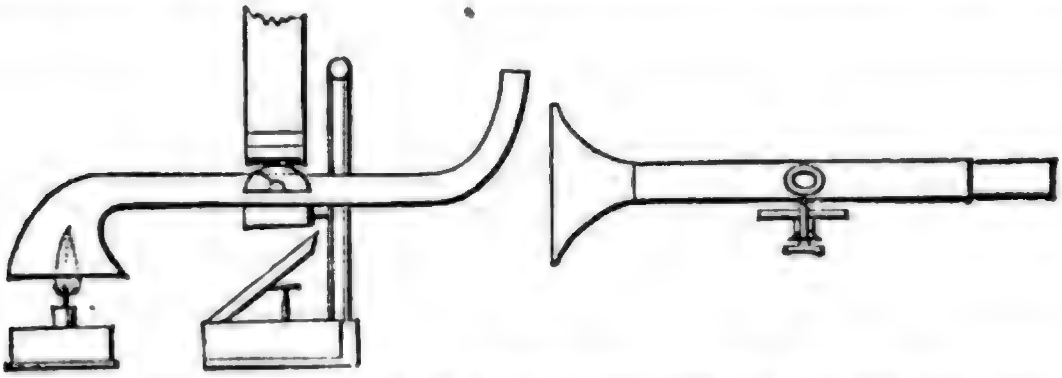
Modifications temporaires.

Ecartement des axes optiques.	Température en degrés Centigrades.
16° axes rouges; plan parallèle à la diagonale horizontale............. 12° à 13° axes bleus; plan parallèle au plan de symétrie.	18°·7

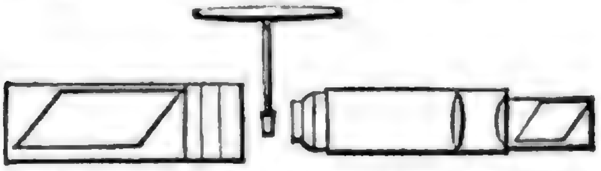
Ecartement des axes rouges dans un plan parallèle au plan de symétrie.		Température en degrés Centigrades.
°	′	°
0		42·5
6		43
7		45
10	30	46
11		48
12		50
13		53
15		56
17		58
18		60
21		63·5
22		70
23		72·5
24		75
25		80
26		82
27		90
28		93
30		100
31		105·5
33		120
34		125
35		128
37		132·5
38	30	142
39		145
40		150
41		155
42		162·5
43		170
44		173
45		182·5
46		190
46	15	195
46	30	204
47		207
47	15	210
48	15	212
49		215
50		225
51		228
52		237
53	30	240
55		250
57		260
57	30	270
57	45	275
58		275
58	15	279·5
58	30	290
58	40	290
59	15	295
60		302
60	30	306
61		312
61	45	315·5
63		319
63	45	329
64		342·5

On voit que l'écartement des axes optiques va toujours en augmentant avec la température, et que l'augmentation est beaucoup plus rapide de 42° à 142° que de 142° à 342°.

Les observations, répétées un grand nombre de fois, ont été faites au moyen d'un goniomètre particulier installé sur un microscope polarisant, dont j'ai donné une description abrégée en 1859 dans le tom. xvi. des 'Annales des Mines,' et que j'ai l'honneur de mettre sous les yeux de la Section. La plaque est soumise à un courant d'air chaud fourni par une lampe à alcool, et circulant dans une cheminée horizontale en cuivre placée sur le microscope; l'écartement des axes optiques peut être mesuré à chaque instant à travers deux ouvertures pratiquées au centre des parois horizontales de la cheminée et munies d'une glace mince; la température de l'air est indiquée en même temps par deux thermomètres placés à droite et à gauche de ces ouvertures.



Mais en employant ce procédé, je ne pouvais pas dépasser une température d'environ 350°. Pour m'assurer si les phénomènes suivaient la même marche au-delà de cette température, j'ai placé mon microscope dans une position horizontale, et sur le prolongement de son axe derrière l'éclaireu j'ai disposé un prisme de Nicol servant de polariseur. Entre l'éclaireur et l'objectif, distants d'environ deux centimètres, j'ai suspendu, à l'aide d'une pince en platine, une très petite lame parfaitement limpide et homogène d'orthose de Wehr sur laquelle pouvait être dirigé le dard d'un chalumeau à gaz; un cercle horizontal gradué, au centre duquel passe la tige qui soutient la pince de platine, permet de mesurer l'écartement des axes optiques; pour plus de facilité j'ai opéré avec un verre rouge monochromatique.



Une plaque, qui à 14° Cent. avait ses axes rouges écartés de 18° 30′ dans un plan parallèle au plan de symétrie, a montré, dès la première application de la chaleur, deux systèmes d'anneaux dont le nombre augmentait rapidement tandis que leur diamètre diminuait; leur forme ainsi que celle des hyperboles qui les traversent a conservé toute sa symétrie jusque vers la naissance du rouge où l'écartement des axes a été trouvé de 70°. Aussitôt que le rouge est devenu apparent, les anneaux et les hyperboles se sont déformés en se brisant, la mesure de l'écartement ne s'est plus faite qu'avec difficulté, et vers 700° elle a donné successivement 2E = 118°, 122°, 124°. L'expérience ayant été arrêtée pour ne pas faire éclater les lentilles du microscope, la plaque s'est refroidie rapidement, les phénomènes optiques ont repassé par toutes les phases qu'ils avaient déjà parcourues, et à 15° Cent. j'ai retrouvé l'angle des axes égal à 19°; il ne s'était donc produit aucune modification permanente. Cette plaque soumise plusieurs fois aux mêmes épreuves a toujours offert des apparences semblables; l'accroissement de température semblait augmenter son épaisseur, et sa structure au rouge se rapprochait de celle que présentent à la température ordinaire certains cristaux de Prehnite, de Heulandite, &c., composés de lames irrégulièrement enchevêtrées.

Une seconde plaque carrée, ayant à 15° Cent. ses axes rouges écartés de 13° dans un plan parallèle à la diagonale horizontale de la base et ses axes bleus écartés de 16° 30′ dans un plan parallèle au plan de symétrie, s'est comportée d'une manière analogue. A partir du rouge naissant le plus foible, les anneaux se déformaient fortement, les hyperboles disparaissaient, et l'angle apparent des axes, qui était considérable, ne pouvait plus se mesurer exactement.

Des résultats précédents il semble permis de conclure que jusqu'à 350° environ la conductibilité calorifique n'éprouve pas de changement notable dans l'intérieur du feldspath orthose, mais qu'à partir de 400° ou 500° la propagation de la chaleur s'y fait d'une manière assez inégale pour provoquer temporairement une perturbation plus ou moins profonde dans l'équilibre de ses arrangements moléculaires. Cet équilibre peut reprendre son état primitif après le refroidissement, si la perturbation n'a duré que 2 ou 3 minutes à une température qui ne dépasse pas 700°. Nous allons voir maintenant qu'en prolongeant l'action de la chaleur pendant un temps suffisant, au rouge sombre ou au rouge blanc, il en résulte une nouvelle disposition physique qui se manifeste par des modifications *permanentes* dans l'orientation et l'écartement des axes optiques.

Modifications permanentes.

1ère plaque d'orthose de Wehr donnant à 13° Centig. avant calcination :

$$2E^{*}=\begin{array}{l}13^\circ \text{ axes rouges, plan parallèle à la diagonale horizontale;}\\ 17^\circ \text{ axes bleus, plan parallèle au plan de symétrie.}\end{array}$$

Après calcination de 1 heure sur une lampe à alcool ordinaire :

$$2E=\begin{array}{l}10^\circ \text{ axes rouges, plan parallèle à la diagonale horizontale;}\\ 21^\circ \text{ axes bleus, plan parallèle au plan de symétrie, à } 13^\circ \text{ Centig.}\end{array}$$

Après calcination de 4 heures sur une lampe à gaz vers 600° à 700° et refroidissement lent de 4 heures :

$$2E=\left.\begin{array}{l}24^\circ \text{ axes rouges,}\\ 30^\circ \text{ axes bleus,}\end{array}\right\}\text{ plan parallèle au plan de symétrie, à } 13^\circ \text{ Centig.}$$

Après une nouvelle calcination de 7 heures sur la lampe à gaz et refroidissement brusque :

$$2E=\left.\begin{array}{l}25^\circ\ 30' \text{ axes rouges,}\\ 32^\circ\ 30' \text{ axes bleus,}\end{array}\right\}\text{ plan parallèle au plan de symétrie, à } 15^\circ{\cdot}5 \text{ Centig.}$$

2ième plaque de Wehr donnant avant calcination à 13° Centig. :

$$2E=\left.\begin{array}{l}22^\circ \qquad\ \text{ axes rouges,}\\ 11^\circ\ 30' \text{ axes bleus,}\end{array}\right\}\text{ plan parallèle à la diagonale horizontale.}$$

Après une calcination de 8 heures sur la lampe à gaz et refroidissement brusque :

$$2E=\left.\begin{array}{l}14^\circ \qquad\ \text{ axes rouges,}\\ 24^\circ\ 30' \text{ axes bleus,}\end{array}\right\}\text{ plan parallèle au plan de symétrie, à } 15^\circ{\cdot}5 \text{ Centig.}$$

Après une exposition de 8 jours, dont 36 heures de calcination vers 800° et 6 jours de refroidissement gradué, dans un four de Sèvres cuisant au *dégourdi* :

$$2E=\left.\begin{array}{l}37^\circ \text{ axes rouges,}\\ 49^\circ \text{ axes bleus,}\end{array}\right\}\text{ plan parallèle au plan de symétrie, à } 19^\circ{\cdot}5 \text{ Centig.}$$

3ième plaque de Wehr très epaisse donnant avant calcination à 12° Centig. :

$$2E=\left.\begin{array}{l}25^\circ \text{ axes rouges,}\\ 17^\circ \text{ axes bleus,}\end{array}\right\}\text{ plan parallèle à la diagonale horizontale.}$$

Après 1 heure de calcination sur la lampe à gaz, pas de changement.

Après 5 minutes de calcination sur un chalumeau à gaz vers 900° et refroidissement brusque :

$$2E=\left.\begin{array}{l}33^\circ\ 30' \text{ axes rouges,}\\ 38^\circ \qquad\ \text{ axes bleus,}\end{array}\right\}\text{ plan parallèle au plan de symétrie, à } 13^\circ \text{ Centig.}$$

Après 8 jours d'exposition dans un four de Sèvres cuisant au *dégourdi* :

$$2E=\left.\begin{array}{l}43^\circ \text{ axes rouges,}\\ 48^\circ \text{ axes bleus,}\end{array}\right\}\text{ plan parallèle au plan de symétrie, à } 19^\circ{\cdot}5 \text{ Centig.}$$

4ième échantillon de Wehr débité en 3 plaques donnant avant calcination à 13° Centig. :

$$2E=\left.\begin{array}{l}17^\circ\ 30' \text{ axes rouges,}\\ 27^\circ \qquad\ \text{ axes bleus,}\end{array}\right\}\text{ plan parallèle au plan de symétrie.}$$

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* 2E désigne l'angle apparent des axes optiques dans l'air.

La 1ère plaque, chauffée pendant 7 heures au rouge foible sur une lampe à gaz et refroidie brusquement, a donné :

2E=21° axes rouges,
29° axes bleus, } plan parallèle au plan de symétrie, à 13° Centig.

Après une calcination de ¼ heure sur un chalumeau à gaz au rouge vif (fusion du cuivre) et refroidissement brusque, l'écartement est devenu :

2E=45° 30′ axes rouges,
49° 30′ axes bleus, } plan parallèle au plan de symétrie, à 15° Centig.

La 2ième plaque exposée à Sèvres pendant 8 jours dans un four chauffant au *dégourdi* et refroidie très lentement, a donné :

2E=46° axes rouges,
52° axes bleus, } plan parallèle au plan de symétrie, à 19°·5 Centig.

Après une nouvelle exposition de 8 jours dans un four cuisant au *grand feu* et un refroidissement très lent, on a obtenu :

2E=48° 30′ axes rouges,
53° 30′ axes bleus, } plan parallèle au plan de symétrie, à 18° Centig.

La 3ième plaque, mise à Sèvres au *grand feu* en même temps que la précédente, a donné :

2E=48° axes rouges,
53° axes bleus, } plan parallèle au plan de symétrie, à 20° Centig.

Plusieurs plaques d'adulaire du Saint-Gothard, calcinées au rouge foible sur une lampe à gaz, n'ont éprouvé aucun changement dans l'écartement de leurs axes optiques.

Une plaque d'adulaire donnant avant calcination, à 16°·5 Centig., 2E=108° axes rouges, a été calcinée pendant ¼ d'heure au rouge vif (fusion de l'argent) sur un chalumeau à gaz ; elle est devenue laiteuse et translucide par places, et à 18° Centig. l'écartement de ses axes rouges n'est plus que de 102° 25′.

Une autre plaque d'adulaire dans laquelle 2E=111° 23′ pour les axes rouges, à 20° Centig. avant calcination, a donné après une ½-heure de calcination au rouge vif sur le chalumeau à gaz, 2E=90° 27′, à 16° Centig. Dans les fours de Sèvres, la teinte laiteuse augmente, la translucidité diminue, et l'angle des axes ne peut plus être apprécié bien exactement.

Une plaque de pierre de lune (*moonstone*) de Ceylan, dans laquelle l'écartement des axes était de 121° 15′ avant calcination, à 15°·5 Centig. a perdu son reflet chatoyant et pris une teinte laiteuse après une exposition de ¼ d'heure sur le chalumeau à gaz (fusion de l'argent), et à 18° Centig. cet écartement est devenu 117° 31′.

En répétant ces expériences sur les variétés d'orthose connues sous les noms de *eisspath* de la Somma, *sanidine* des trachytes des bords du Rhin et de l'Auvergne, *loxoclase* de New York, *microcline* de Fredrikswärn (variété chatoyante) ou de Bodenmais (variété verte non chatoyante), *Murchisonite* du Devonshire, *hyalophane* de Binnen, j'ai trouvé que toutes éprouvent sous l'influence de la chaleur des modifications permanentes et temporaires analogues à celles du feldspath vitreux de Wehr. Calcinés au rouge sombre ou au rouge vif, les échantillons les plus transparents et les plus homogènes, comme ceux de Wehr et de la Somma, conservent leur aspect primitif sans autre changement apparent que celui des fissures, parallèles à leurs deux clivages rectangulaires, qui deviennent plus prononcées ; d'autres prennent une teinte laiteuse plus ou moins marquée ; d'autres enfin, comme ceux des trachytes, deviennent presque complètement opaques. Dans tous les cas, la perte en poids ne dépasse pas 1 milligramme par gramme, quant aux axes cristallographiques leur orientation ne paraît pas changer d'une manière appréciable, car j'ai trouvé sur plusieurs plaques qu'une base produite par clivage faisait avant et après calcination, avec la face artificielle normale à la bissectrice aiguë, un angle identique à une ou deux minutes près.

Les feldspaths du sixième système cristallin n'éprouvent par la chaleur aucun changement temporaire ou permanent dans leurs propriétés optiques biréfringentes. Les axes optiques y sont toujours orientés à très peu-près comme dans l'albite, et leur bissectrice aiguë est positive ; leur écartement dans l'air dépasse 135°. Il paraît donc bien probable que, quelque ait été le mode de formation des feldspaths tels que l'*albite*, l'*oligoclase*, le *labradorite* et l'*anorthite*, ils n'ont pas été soumis dans la nature aux mêmes influences que ceux dont l'orthose est le type.

Les cristaux de cymophane ($Hl\,O, Al^2\,O^3$) du Brésil, et ceux de Brookite ($Ti\,O^2$) de la Tête noire en Valais et du Dauphiné, offrent souvent des plages dans lesquelles les axes optiques présentent à la température ordinaire des écartements très differents et une orientation qui peut avoir lieu dans deux plans rectangulaires entre eux, avec une dispersion d'autant plus considérable que l'écartement est plus petit. Il existe donc une grande analogie entre la constitution physique de ces deux minéraux et celle des feldspaths du cinquième système cristallin. Aussi la calcination détermine-t-elle dans leurs propriétés optiques des modifications permanentes et temporaires entièrement semblables à celles que j'ai découvertes dans l'orthose. Si l'on rapporte les formes de la cymophane à un prisme rhomboïdal droit de 119° 46′, on voit que dans les cristaux du Brésil les plus transparents et les plus homogènes, le plan des axes optiques est normal à la base et la bissectrice aiguë *positive*, parallèle à la petite diagonale de cette face. L'angle des axes correspondant au rouge peut s'élever jusqu'à 120°, et celui des axes correspondant au bleu jusqu'à 118°. Certaines plages à reflets opalins montrent des axes rouges réunis et des axes bleus séparés dans un plan parallèle à la base; d'autres plages font voir les axes correspondant à toutes les couleurs séparés dans ce même plan. Une élévation de température a pour effet de rapprocher les axes orientés parallèlement à la base et d'écarter ceux dont l'orientation lui est perpendiculaire. Jusqu'au rouge naissant les changements ne sont que temporaires, mais une calcination de 15 minutes à la température de la fusion de l'argent suffit pour les rendre permanents et déjà considérables. La perte en poids est, comme pour l'orthose, de 1 milligramme par gramme, et l'aspect extérieur de la substance n'est nullement modifié.

Pour la Brookite dont on peut faire dériver les formes d'un prisme rhombique de 99° 50′, le plan des axes optiques est tantôt parallèle, tantôt perpendiculaire à la base; la bissectrice est *positive* et reste toujours parallèle à la petite diagonale de cette face. La dispersion est très considérable, et lorsque les axes sont situés dans le plan de la base, les rouges sont plus écartés que les violets; leur écartement augmente d'une manière temporaire par une calcination foible, et d'une manière permanente par une calcination plus énergique. Dans un échantillon du Dauphiné où l'angle des axes était de 52° à 20° Centig. j'ai observé temporairement un écartement de 65° à 220° Centig. Une autre plaque, chauffée avec précaution dans une moufle, a éprouvé une modification permanente qui a porté l'angle de ses axes rouges de 42° à 47°.

Les perturbations permanentes que le changement de température apporte dans l'équilibre moléculaire du feldspath orthose ayant également lieu dans la cymophane et la Brookite, sont évidemment indépendantes de la composition chimique des corps cristallisés. Les expériences faites dans les fours de Sèvres, où le refroidissement est très lent, ne permettent pas d'ailleurs d'attribuer ces perturbations à des effets de trempe, comme on pourrait être tenté de le faire au premier abord; on peut donc les regarder réellement comme en rapport avec la constitution physique de certains cristaux, et l'on doit admettre que la position des axes optiques ainsi que leur dispersion est susceptible de varier dans une même espèce minérale avec la température à laquelle les cristaux *sont* ou *ont été* soumis.

On the Mode of preparing Carbonic Acid Vacua in large Glass Vessels.

By J. P. Gassiot, *F.R.S.*

During the process of preparing carbonic acid vacuum-tubes for his experimental researches on the Stratified Electrical Discharge (Philosophical Transactions, 1859; Proceedings, 1860–1861), the author ascertained that when the stopper of a glass vessel is very carefully ground, the vacuum will remain without the slightest alteration for many months: among a variety of tubes thus prepared, he has one with four glass stoppers, three of which are nearly one inch in diameter. It is upwards of twelve months since this vacuum was prepared, and to the present time, whenever the discharge from an induction coil is passed through it, there is not the slightest alteration in the appearance of the striæ.

If a larger aperture is requisite instead of the stopper, all that is requisite is to

have the two surfaces of the glass very carefully ground, in the same manner as the bell-glasses for an air-pump are prepared; by these means glass vessels of almost any required dimensions can be used, provided care is taken that the form is such as will resist the pressure of the atmosphere.

The potash necessary to absorb the residue of the carbonic acid after the exhaustion by the air-pump, may be placed at the bottom of the vessel, and gently heated on a sand-bath or by a spirit-lamp, or it may be placed in a tube, and subsequently sealed off by the blowpipe.

On the Essential Oil of Bay, and other Aromatic Oils.
By J. H. Gladstone, *Ph.D., F.R.S.*

This paper consisted of—1st. A description of the essential oils of Bay, Bergamot, Carraway, Cassia, Cedar-wood, Cedrat, Citronella, Cloves, Indian Geranium, Lavender, Lemon Grass, Mint, Neroli, Nutmeg, Patchouli, Petit-grain, Portugal, Rose, Santal-wood, Turpentine, and Winter-green, with the specific gravities and powers of refraction, dispersion, and circular polarization. 2nd. Some remarks on the isomeric hydrocarbons, which may be derived from the majority of the essential oils, and which generally resemble each other very closely, though they are rarely identical. 3rd. Notices of some of the oxidized bodies present in these oils, which are generally more refractive and more aromatic than the hydrocarbons of which they are oxygen substitution products.

Among the observations were the following:—Oil of Bay consists of a hydrocarbon of the ordinary type, $C_{20}H_{16}$, and eugenic acid. Oil of Neroli contains two hydrocarbons, one of which is a fluorescent body. The essential oil of Petit-grain, which is derived from the leaves of the orange-tree, contains a hydrocarbon resembling the more volatile one from oil of Neroli, which is prepared from the orange flower; and so does the oil of Portugal, from the orange peel. Otto of roses is an oxidized oil; the crystallizable portion of it has a great attraction for ether vapour. The oils of Citronella and of Lemon-grass, from different species of *Andropogon*, cultivated in Ceylon, consist mainly of oxidized oils which are nearly if not quite identical. There is a very wide difference in the action on the polarized ray exerted by different essential oils, both in regard to amount and direction.

On the Means of observing the Lines of the Solar Spectrum due to the Terrestrial Atmosphere. By J. H. Gladstone, *Ph.D., F.R.S.*

The object of this communication was to incite observers in various parts to notice those lines and bands which appear in the spectrum when the sun is near the horizon. They vary under different atmospheric conditions, and probably in different parts of this and other countries. The author had found one of Crookes's pocket spectroscopes sufficiently powerful to exhibit all the most important of them, and very convenient for taking up mountains, &c. All observations should be referred to the map published in the Philosophical Transactions for 1860.

On a particular Case of induced Chemical Action.
By A. Vernon Harcourt, *M.A.*

It has been observed by Mohr, Scheurer-Kestner, and other chemists, that when a protosalt of tin is determined by means of a standard permanganate solution, the results obtained vary according to the degree in which the solution of tin-salt is diluted. The greater the dilution, the less is the amount of permanganate required. This variation is justly ascribed by the two chemists above named to the influence of the oxygen which the water used in diluting holds dissolved. With recently boiled water, the effect is less; with water which has been absolutely freed from air, it disappears.

If these facts stood alone, their explanation would seem simple, viz. that chloride of tin is speedily oxidized when mixed with water containing oxygen. But this is not the case, especially when much free acid has been added. If iodine, or perchloride of iron, or sulphate of copper is used as the oxidizing agent, the result of the determination is the same, whether the tin solution be little or much diluted.

Hence it appears that in the former case the action of the dissolved oxygen is determined by the action of the permanganate*.

In order to investigate quantitatively the relation of these two actions, several series of determinations were made in the following manner:—A measured quantity of a solution of protochloride of tin of convenient strength was determined, first without dilution, and then, in successive experiments, after dilution with regularly increasing quantities of water. Immediately before and during each determination, a stream of carbonic acid was poured into the flask containing the liquid to be determined, in order to guard it from contact of air. The conclusions to which these experiments have led are as follows:—(1) When the diluting water contains only so much oxygen as is sufficient to oxidize about one-third of the protochloride of tin present, the whole of this oxygen is appropriated in the reaction; (2) after this point, the amount of induced oxidation is still increased by further dilution, but in a continually diminishing degree, until it bears to the primary oxidation (that by the permanganate) about the ratio of 2:3; (3) still greater dilution produces no further change. It has not yet been found possible to determine the exact ratios of the primary and of the induced oxidation one to another at that point at which the absorption of dissolved oxygen ceases to be complete, and at the final limit, where the induced oxidation has reached a maximum.

With what other chemical actions are we acquainted which belong to the same class as this action?

Four examples may be adduced of actions more or less analogous. 1. The action of platinum-black, and other similar substances, in causing oxidation. These substances, however, do not, so far as we know, themselves undergo any change; whereas the permanganate can act inductively only during the moment of its own direct action. 2. The action of nitric oxide upon sulphurous anhydride and oxygen. 3. The action of pentachloride of antimony in presence of free chlorine in causing the formation of chlorine compounds. But in these two cases also an important distinction is to be noted. The products of the initial action, nitrous oxide and terchloride of antimony, are capable of combining directly with free oxygen and free chlorine respectively; whereas the final product at least of the reduction of an acid solution of permanganate is not liable to reoxidation, and such a solution can accordingly be reduced by many substances in the presence of dissolved oxygen without appropriating or conveying it. 4. The acetous fermentation. The fact that the oxidation of alcohol by free oxygen may be induced by the presence of other substances undergoing chemical change bears some resemblance to the fact here brought forward. It is not improbable that the two may depend upon a common cause.

But no case that has been yet examined is directly and unmistakeably parallel to this action. At the same time, it is doubtless but one of a class. The action of other similar oxidizing bodies, such as chromic acid, and of other substances readily susceptible of oxidation, such as sulphurous acid, hydriodic acid, &c., in presence of dissolved oxygen, may probably present similar phenomena. With the action, in dilute solutions, of chromic acid on sulphurous acid, and permanganic acid on sulphurous acid, this has been ascertained to be the case.

On Schönbein's *Antozone.*

By G. Harley, *M.D., Professor in University College, London.*

In 1842 Schafhäutl called attention to a fluor-spar, the peculiar smell of which he imagined to be due to the presence of hypochlorite of lime. Schönbein shortly afterwards found that it contained an oxidizing agent which Schrötter subsequently described as ozone. Schönbein has now repeated his experiments on a better quality of the mineral, and finds that the oxygen contained in it resembles that yielded by BaO_2; and that distilled water in which the mineral has been pounded acquires peculiar properties. At the request of Professor Liebig, who had given Dr. Harley some fine specimens of the mineral, the latter gentleman showed some of the more striking properties of the mineral to the members of the Association. For example, the distilled water in which the mineral has been pulverized, when filtered gives no precipitate with nitrate of silver, and only the very slightest turbidity with oxalate of ammonia and with weak sulphuric acid. From this it is seen that no chlorine is present, and only a trace of an earthy base. The liquid blues iodized starch, decolorizes a solution of permanganate of potash acidified with sulphuric acid, at the same time liberating oxygen gas. The liquid gives a blue with the brownish mixture of dilute ferridcyanide and perchloride of iron, and gradually precipitates prussian blue. When mixed a short time with the peroxide of lead and finely reduced platinum-powder, it loses some of the above-named properties. Heating the mineral entirely destroys its properties. Schönbein concludes from these and other facts that the mineral contains antozone.

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* Since reading the paper of which the above is an abstract, the author has become aware that this fact had already engaged the attention of the German chemist Löwenthal, who, in conjunction with E. Lennsen, has recently shown that dissolved oxygen is similarly rendered active in some other cases (Journ. für Prakt. Chem. 1859, part i. p. 484, and vol. lxi. (1862) p. 193).

On the Adulteration of Linseed Cake with Nut-cake.

By W. H. Harris, *F.C.S.*

The frequent adulteration of linseed cake, used for cattle-feeding purposes, has drawn considerable attention on the part of the agricultural chemist to the different adulterative substances employed by the trade. Many of these have been from time to time exposed. But there is one substance largely used for adulterating linseed cake, which has not, that I am aware of, received the notice which it deserves. The substance I refer to is the market nut-cake, obtained from the fruit of the *Arachis hypogea*, or Ground-nut of America, indigenous to Mexico, but cultivated in the West Indies. As botanists are aware, it derives its name from the singular manner in which its fruit is perfected; for as its yellow papilionaceous flowers fall from their stalks, the pods which follow are forced by a natural motion of the plant into the ground, where the seeds ripen and come to perfection—hence the name of Ground-nut.

As the cake composed of the marc of these seeds can be purchased at about half the price of linseed cake, it is often used for the purpose of adulteration—a fact patent to most agricultural chemists. But this substance seems to have been generally condemned as a worthless article; for we have seen this verdict given against it in several instances by eminent agricultural chemists; at any rate, if I am mistaken in the article of commerce which has been classed with bran, rice dust, and treated as rubbish, the mistake is attributable to an unfortunate looseness of language adopted by the authorities in question.

My attention being directed to the true feeding qualities of this substance was accidental; for having to analyse a sample of linseed cake which contained a considerable quantity of bran, I was surprised to find the analytical result, in reference to the percentage of flesh-formers, was considerably superior to the result I had obtained from many genuine samples I had analysed. This led me to resubmit the cake to a careful microscopic examination, which enabled me to detect what afterwards proved to be the decorticated nut-cake of commerce.

My next step was to get a sample of this nut-cake in its simplicity; this, through the kindness of a gentleman connected with the trade, I succeeded in doing. On submitting this sample to analysis, the result exceeded my highest expectations, as the following results of the examination will show:—

	Per cent.
Moisture	8·50
Ash	4·94
Cellulose, insoluble in warm solution of potash, sp. gr. 1045	3·51
Albuminous compounds[*]	43·31
Amylaceous constituents	27·34
Oil	12·40
	100·00

To be able to introduce to the cattle-feeder a highly nutritious substance, capable of sustaining a successful competition with linseed cake itself, and not more than two-thirds the market value of the latter, it now only remained to prove that its practical answered to its theoretic value. Of this there did not appear to me to be any serious doubt; nevertheless I thought it better to put the matter to the test of practical experiment. A friend to whom I named the subject readily entered into the plan of trying the effect of this cake upon a portion of his stock; the result proved his cattle would eat it with eagerness, and, as far as the experiment has gone, it has answered our highest expectations.

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[*] Containing nitrogen 6·93 per cent.

On a Simple Method of taking Stereomicro-photographs.

By CHARLES HEISCH, *F.C.S., Lecturer on Chemistry at the Middlesex Hospital.*

After trying various plans, the author devised the following, which answered perfectly. A microscope with its eyepiece removed is placed in a horizontal position, and fitted to an ordinary sliding back, single lens, stereoscopic camera. Behind the object-glass is screwed an adapter, in the inside of which is a tube, which can be turned half round by means of a lever from the outside. Sliding in this tube is a second, furnished with a stop which cuts off half the pencil of light coming from the object-glass, in fact occupies the same place as the prism of a binocular microscope. The distance of this stop from each object-glass is adjusted experimentally by sliding the tube backwards and forwards till the best effect is obtained. The prepared plate being put in its place after carefully focusing the object, the first picture is taken. The plate is then shifted, the stop turned half round, and the second picture taken on the other half of the plate. If the object be of any thickness, its upper surface should be focused for one picture, and its under surface for the other.

The adapter with its stop was exhibited to the meeting.

Lowe's Ozone Box. *By* E. J. LOWE, *F.R.A.S. &c.*

This box has been constructed so as to ensure perfect darkness to the test-paper without interfering with the passage of a current of air. There are two openings into this cylindrical box, the one above and the other below. These openings are not direct into the box itself, but into narrow winding passages in the first instance; they are also opposite each other. If the wind is blowing in an easterly current, and the upper opening is on the east side, then the air will enter the box on the upper half (fig. 1), will move round the circular passage until it enters the central cavity (A) where the test-paper is hung, afterwards passing round the lower passage (fig. 2) in a contrary direction, and out again at the west aperture. Or if the wind happens to be in the opposite direction, it will enter from below and leave the box from above. The advantage is obvious—a current of air passes through a *dark* chamber. The box is small, and its price almost nominal.

Fig. 1.

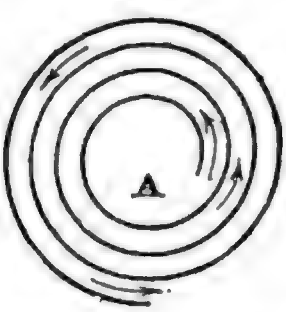
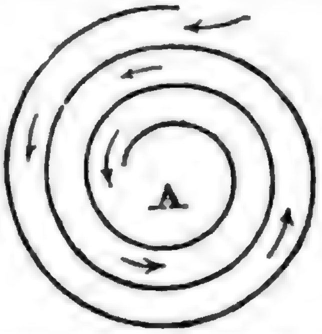


Fig. 2.



Observations on Ozone. *By* E. J. LOWE, *F.R.A.S. &c.*

The following are results of observations made at the Beeston Observatory during the past four years:—

1st. If the temperature is raised, the amount of ozone will increase.

2nd. If the current of air through the box increases in rapidity, the amount of ozone will increase.

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3rd. As the barometer becomes lower, the amount of ozone becomes greater.

1st. If the temperature be ranged in 10° series, a temperature between 30° and 40° will give less ozone than one between 40° and 50°, and this less than one between 50° and 60°. Artificially, if a night-light be made to burn in a cell below the box so as to warm it, there will be an increase in the amount of ozone over another box that is without a night-light.

2nd. With respect to an increase in ozone resulting from an increase in the speed of the air, it is shown from this series of observations that the most ozone has been present when there has been a gale blowing. It does not necessarily prove that under these circumstances there is actually more ozone in the air; for it must be borne in mind that if the amount of ozone in a cubic foot of air were always the same, still if today 300 cubic feet of air only occupies the same space of time in passing through the box as 100 cubic feet occupied yesterday, we shall have more ozone apparently shown today than yesterday. Then again, as chemical action increases with an increase of heat, it is also manifest that the same amount of ozone passing through the box at a temperature of 60° would necessarily darken the paper more than the same amount at a temperature of 40°.

It is quite clear that certain corrections are requisite in order to find the actual amount of ozone.

3rd. With regard to the pressure of the air, there is a striking difference between the readings of the ozonometer with a high or low barometer. Taking the four days in each month during the past year on which the mean pressure was greatest, the average amount of ozone was 1·2, whilst on taking the same number of days when the barometer was lowest, the mean was 4·1, or nearly four times as much; four years' observations give very similar results. The mean maximum pressure for the whole twelve months of the four years is 30·22 inches, the mean ozone being 1·0; the mean minimum pressure for the like period is 29·18 inches, the mean ozone being 3·2.

With the barometer at	28½	inches the mean ozone is	5·7
„	28¾	„ „	4·1
„	29	„ „	3·5
„	29¼	„ „	2·8
„	29½	„ „	2·0
„	29¾	„ „	1·6
„	30	„ „	1·3
„	30¼	„ „	0·5
„	30½	„ „	0·4

There is a difference between the amount of ozone during the night and day at different seasons.

In December and January	an excess at night over the day of	0·8
In February and March	„ „	0·7
In April and May	„ „	0·7
In June and July	„ „	0·1
In August and September	„ „	0·4
In October and November	„ „	0·5

The average of the summer months being in excess only one-half of that which occurs in the winter.

On the Luminosity of Phosphorus. *By* Dr. Moffat.

If a piece of phosphorus be put under a bell-glass and observed from time to time, it will be found at times luminous, and at others non-luminous. When it is luminous, a stream of vapour rises from it, which sometimes terminates in an inverted cone of rings similar to those given off by phosphuretted hydrogen; and at others it forms a beautiful curve, with a descending limb equal in length to the ascending one. Results deduced from daily observations of the phosphorus in connexion with the readings of the barometer, the temperature and degree of humidity of the air, with directions of the wind, for a period of eighteen months, show that periods of luminosity or phosphorus and non-luminosity occur under opposite conditions of the atmosphere. By the catalytic action of phosphorus on atmospheric air, a gaseous body (superoxide of hydrogen) is formed, which is analogous to, if not the same as, atmospheric ozone, and it can be detected by the same tests. The author has found, by his usual tests, that *phosphoric* ozone is developed only when the phosphorus is luminous.

On Ferrous Acid. By W. Odling, *M.B., F.R.S.*

The author found that when ferric oxide was ignited with the carbonates of potassium, sodium, and calcium, each atom of $fe_2\,\Theta_3$ drove out one of $C\Theta_2$, to form two atoms of an alkaline ferrite, having the general formula $M\,fe\,\Theta_2$, which salts were decomposed by water into caustic alkali and ferric monohydrate or brown hæmatite; thus, $M\,fe\,\Theta_2 + H_2\,\Theta = H\,fe\,\Theta_2 + MH\Theta$.

On the Synthesis of some Hydrocarbons. By W. Odling, *M.B., F.R.S.*

The author found, in particular, that when a mixture of carbonic oxide and marsh-gas was passed through a red-hot tube, acetylene was abundantly formed according to the equation $C\Theta + CH_4 = C_2H_2 + H_2\Theta$.

On the Nomenclature of Organic Compounds. By W. Odling, *M.B., F.R.S.*

Admitting the impossibility of establishing a thoroughly systematic nomenclature in organic chemistry, the author advocated a gradual improvement of that now in more or less general use, by removing its chief incongruities, and remedying its more striking inconveniences. He showed, by many examples, how great an improvement might be effected by an introduction of very few and trivial changes.

On the Essential Oils and Resins from the Indigenous Vegetation of Victoria.

By J. W. Osborne.

The indigenous trees and shrubs of the colony of Victoria belong for the most part to the genera *Eucalyptus* and *Melaleuca*, which grow in great luxuriance over the greater part of the Australian continent. In no other localities are oil-bearing plants to be found in the same abundance, especially such as attain to arborescent growth, nor is the yield of oil as great elsewhere. The thirty-five samples submitted to the Section are identical with those exhibited in the Victorian Department of the International Exhibition. They were distilled by the Exhibitors, at the request and under the auspices of Dr. Ferdinand Müller, the Government Botanist of Victoria, to whose great talents and untiring energy the colony is largely indebted. In the present case the rigorous accuracy of the specific name of each specimen may be accepted on his authority.

The author, as Juror, examined the essential oils and resins with respect to their technological value, for the Victorian Commissioners.

Those from the genera *Eucalyptus* and *Melaleuca* (nineteen different oils) resemble the Cajuput of India, *Melaleuca leucadendron*. In smell and taste they are generally more camphoraceous, partaking sometimes of the odour of oil of lemon. Their colour is for the most part a pale yellow, sometimes colourless, and occasionally green. Their specific gravity, in the samples submitted to the Section, varies from 0·881 to 0·940, the average being about 0·910. These oils have all two boiling-points, the lower being, generally speaking, about 325°, and the other about 40° higher.

They burn well in suitable lamps, and are not dangerous, as they are ignited with difficulty. As solvents for resinous bodies, they surpass most liquids of the kind, and form varnishes, attacking with readiness the intractable Kauric gum of New Zealand. The yield from individuals of the series is sometimes exceedingly large, *E. amygdalina* giving by distillation of 100 lbs. of its green leaves and branchlets, three pints of oil; *E. oleosa*, 20 ounces; *E. sideroxylon*, 16 ounces; *M. linarifolia*, 28 ounces, &c. It is estimated that 12,000,000 acres of the colony of Victoria are covered with myrtaceous vegetation of this description, some of it of a shrubby character, densely covering vast tracts (*E. oleosa*, F. M.; *E. dumosa*, Cunn.; *E.*

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socialis, F. M., all known as Mallee Scrub). The other oils were chiefly endowed with medicinal characteristics, including several true mints, *Mentha Australis*, *M. gracilis*, and *M. grandiflora*; also some related to plants of the Rue species, and one fragrant perfume distilled from the blossoms of the *Pittosporum undulatum*. Also a heavy oil from the bark of the *Atherosperma moschatum*, possessed of powerful medicinal properties.

The resins and gum-resins include several obtained from the genus *Eucalyptus*, which are powerfully astringent, and more or less soluble in water. Also one from the *Callitris verrucosa* and *cupressiformis* of Northern Victoria, the sandarac of commerce; one from the *Xanthorrhœa australis*, a balsamic resin containing benzoic acid, and resembling dragon's-blood; together with some true gums from the genus *Acacia*, which is well represented in the Australian colonies.

The following is a list of the oils submitted to investigation, with their vernacular names as far as known.

Eucalyptus amygdalina (Daudenong Peppermint).
E. oleosa (Mallee Scrub).
E. sideroxylon (Iron-bark).
E. zonicalyx (White Gum).
E. globulus (Blue Gum).
E. corymbosa (Blood-wood).
E. fabrorum (Stringy-bark).
E. fissilis (Messmate).
E. odorata (Peppermint).
E. Woollsii (Woolly-butt).
E. rostrata (Red Gum).
E. viminalis (Manna Gum).
Melaleuca linariifolia.
M. curvifolia.
Melaleuca ericifolia (Common Tea-tree).
M. Wilsonii.
M. uncinata.
M. genistifolia.
M. squarrosa.
Atherosperma moschatum (Sassafras).
Prostanthera lasianthos.
P. rotundifolia.
Mentha australis.
M. grandiflora.
M. gracilis.
Zieria lanceolata.
Eristemon squameus.
Pittosporum undulatum.

Details of a Photolithographic Process, as adopted by the Government of Victoria, for the publication of Maps. By J. W. OSBORNE.

The author referred to his having read a paper upon this subject before the Royal Society of Victoria, in November 1859, his process having been previously patented in the Colony on the 1st of September, 1859. The process had then been adopted by the Government, and had come into active use in the Department of Lands and Survey at Melbourne. By its means many hundreds of maps had been published, of a quality and for a price which left nothing to be desired. The Victorian Government had recently erected an office, the design and arrangements of which were admirably adapted for the prosecution of this description of work. To produce a photolithographic copy with or without reduction, the original map or engraving was extended upon an upright board, and by the help of a camera placed opposite, a negative of it was taken. A sheet of paper was now prepared by coating one of its surfaces with a solution of gelatine in water, to which a certain proportion of bichromate of potash and liquid albumen had been added. The surface thus prepared, after it had dried in a dark and warm room, was sensitive to the chemical action of light, and the next operation was to expose to the sun's rays a suitable piece of it, in an ordinary pressure frame, under the negative already obtained. The positive photographic print thus produced was inked all over with lithographic re-transfer ink, and was then placed floating upon boiling water, with its inky side upwards and unwetted. After a short time the gelatine would be found to have softened and swelled under the ink, save where the light had acted, the organic matter upon such places having suffered a peculiar change. Another effect of the boiling water was to coagulate the albumen in the film. When sufficiently soaked, the superfluous ink was removed by means of a sponge, and the result was a photographic print in greasy ink; inasmuch as the latter substance adhered firmly to all the unsoftened, or, in other words, the altered parts of the gelatinous coating. It would also be found that the delineation thus obtained was upon a smooth sur-

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face of coagulated albumen. Boiling water in abundance was now poured over the paper, after which it was carefully dried. The photographic print thus produced, in consequence of the greasy ink upon the positive portions of the work, was capable of being transferred to stone by the printer, by the well-known mechanical process; and from stones thus prepared, impressions could be pulled in the lithographic press.

Numerous specimens were exhibited to the Section.

On the Manufacture of Hydrocarbon Oils, Paraffin, &c., from Peat.

By B. H. Paul, Ph.D.

The author described the results that had been obtained at some works lately erected under his direction in the island of Lewis, N.B. The peat of that locality was described as a peculiarly rich bituminous variety of mountain peat, yielding from five to ten gallons of refined oils and paraffin from the ton. The results obtained at these works were contrasted with those obtained at the works of the Irish Peat Company some years ago, where the produce of oil was not more than two gallons from the ton of peat. This difference in the produce was ascribed, in a great degree, to the improper mode of working adopted at the Irish works. One of the most important points dwelt upon was the necessity of regarding the hydrocarbon oils and paraffin as the only products that would afford a profit in working peat; and the failure of the Irish works was attributed to the attempt to obtain other products which could only be regarded as waste, and not worth working, unless the oils and paraffin were obtainable in a remunerative amount from the peat.

On the Decay and Preservation of Stone employed in Building.

By B. H. Paul, Ph.D.

The causes and nature of the decay of building-stone were described as being both chemical and mechanical, and varying according to the nature of the stone and the conditions to which it was exposed. The various methods which have been proposed for the preservation of stone from decay were described in detail; the author considering, from a chemical point of view, that none of them presented any probability of success in effecting the desired result, and that the discovery of an efficient and practicable means of preventing the decay of stone, especially in towns, still remains to be made.

On the Artificial Formation of Populine, and on a new Class of Organic Compounds. *By* T. L. Phipson, *M.B., Ph.D., F.C.S. &c.*

The interesting substance populine was extracted in 1830 by Braconnot from the mother-liquors which had deposited salicine when the latter was obtained from the leaves and the bark of the poplar tree (*Populus tremula*). It was submitted to an important series of experiments by Piria in 1852, who found, among other interesting facts, that, in a variety of circumstances, populine split up into benzoic acid and salicine:—

$$C^{40}H^{22}O^{16} + 2HO = C^{14}H^{5}O^{3}, HO + C^{26}H^{18}O^{14}.$$

Populine. Benzoic acid. Salicine.

It occurred to me that salicine and benzoic acid might be combined so as to reproduce populine. And this I find to be the case: when equal equivalents of salicine and benzoic acid are dissolved in alcohol and the liquid evaporated to about half its bulk, magnificent acicular crystals of populine are obtained, some of which in my experiments measured nearly an inch in length. For every 100 parts of salicine must be taken 43 parts of benzoic acid. Or for 100 parts of salicine, 53·5 parts of benzoate of soda and a sufficient quantity of diluted sulphuric acid to saturate the soda of the benzoate; alcohol is then added, and the sulphate of soda separated by filtration. By evaporating the solution long needles of populine are obtained:—

$$C^{14}H^{6}O^{4} + C^{26}H^{18}O^{14} = (C^{40}H^{22}O^{16} + 2HO).$$

Benzoic acid. Salicine. Crystallized populine.

The properties of the populine thus formed are precisely those of the natural product. Its peculiar taste, acrid and sweet at the same time, reminding us of the taste of liquorice, is characteristic. With sulphuric acid it takes a red colour; distilled with bichromate of potash and sulphuric acid it yields salicylous acid. It is more soluble in water and alcohol than salicine. It is curious also to note that in this combination the salicine has lost its bitter taste, which renders it probable that populine is in reality a compound of benzoic acid, sugar, and saligenine; for, when boiled with dilute sulphuric acid, it breaks up into benzoic acid, sugar, and saliretine (saligenine *minus* 2 equivs. of water):—

$$\begin{array}{ll} C^{14}H^{8}O^{4} & \text{Saligenine.} \\ C^{12}H^{10}O^{10} & \text{Sugar.} \\ C^{14}H^{6}O^{4} & \text{Benzoic acid.} \\ \hline C^{40}H^{24}O^{18} & \text{Populine.} \end{array}$$

As soon as the sugar is set free, it takes up 4 equivs. of water and passes into grape-sugar ($C^{12}H^{14}O^{14}$).

The molecule of populine is therefore a very complex one. And these kinds of compounds may, perhaps, be compared to the combinations of two or more salts in mineral chemistry, for instance to *alum*, if we compare the sulphate of alumina to the benzoic acid, the sulphate of potash to the saligenine, and the 24 equivalents of water to the sugar.

But I have also found that citric acid and tartaric acid, when taken in equivalent proportions, dissolved in water, and the solution evaporated, enter into chemical combination. It is well known that these acids crystallize in two different systems, the forms of which are incompatible, and by evaporating a mixture of them we should obtain two kinds of crystals if no combination took place. But I find that they combine and produce one kind of crystal only, namely, long prismatic needles, and when one of these crystals is taken and analysed, it is found to be composed of citric and tartaric acids.

This combination of citric and tartaric acids is probably only one example of a new class of organic compounds, similar in some respects to populine, which remains to be studied. Already Prof. Williamson has shown that the different *acetones* may be made to combine so as to produce complex acetones. Thus when valerate and acetate of lime are distilled together in equivalent proportions, we obtain *acetovalerone*, a compound of acetone and valerone, and so on for the others.

It is highly probable from what precedes that other organic acids besides benzoic acid may be made to combine with salicine; likewise that other bitter principles analogous to salicine may be combined with organic acids to produce substances similar to populine.

On the Existence of Aniline in certain Fungi which become Blue in contact with the Air, &c. By T. L. PHIPSON, *M.B., Ph.D., F.C.S. &c.*

Two years ago I published in Brussels a memoir upon the *Boleti* which become blue when cut with a knife, and upon the formation of colouring matters in fungi*. In this paper I called attention to a remarkable set of reactions occurring in nature when one substance causes atmospheric oxygen to assume the state of ozone and to act upon another substance in contact with the first, a fact originally pointed out by Prof. Schœnbein. In this paper also I endeavoured to show that the production of the blue colour observed when *Boletus cyanescens*, *Boletus luridus*, &c. are cut with a knife and exposed to the air, is owing to the existence of *aniline* in the sap of these fungi.

Nothing is easier than to extract the principle to which these *Boleti* owe their remarkable property of taking a deep, though fugitive, blue colour when their internal tissue is put in contact with the air. But it is not easy to obtain it perfectly pure, and very difficult to obtain it in any quantity, as its power of producing the blue colour is so great that a very minute proportion suffices to colour the entire tissue of a large *Boletus*. When one of these fungi is treated with ordinary alcohol, the aniline it contains is dissolved with several other matters, which, however, do not prevent the ordinary characteristic reactions of aniline. This principle appears to be present in the fungus as *acetate* of *aniline*. I have not extracted it in sufficient quantity or of sufficient purity to submit it to more than a qualitative examination; but the data which follow will, I think, sufficiently establish the point in question. I give here, in the form of a Table, the characters observed, of the principle extracted from these *Boleti*, together with the characters of aniline. In every case the result is identical for both:—

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* Sur les Bolets bleuissants : étude sur la formation de principes colorants chez plusieurs Champignons (Journal de Médecine et de Pharmacologie, Bruxelles, Mars et Avril 1860). See also 'Comptes Rendus de l'Acad. des Sciences,' Paris, 1860, 2ième semestre. Also my prize memoir, "La Force Catalytique : études sur les phénomènes de contact," to which the Dutch Society of Science awarded their Gold Medal, Haarlem, 1858.

Characters of the colouring principle of the Boletus.	*Characters of* Aniline.
1. Colourless.	1. Colourless.
2. Very slightly soluble in water.	2. Very slightly soluble in water.
3. Soluble in alcohol.	3. Soluble in alcohol.
4. The alcoholic solution resinifies sooner or later in the air, becoming yellowish.	4. Its solution resinifies in the air and takes a yellow colour.
5. Does not become blue by ordinary atmospheric oxygen unless this oxygen is in the state of ozone.	5. Does not become blue by ordinary atmospheric oxygen unless the latter be in the state of ozone.
6. Gives a deep *blue* colour with ozone, or nascent oxygen; this colour is ephemeral, and is sometimes *greenish*, passing to *wine-colour* or *rose tint*.	6. Gives a deep *blue* with ozone; the colour is ephemeral, and passes to *wine-colour*; with some salts of aniline a *greenish* blue is produced; others give a *rose tint* when exposed to the air.
7. Chloride of lime or bleaching powder developes the characteristic *blue* or *greenish blue* given by aniline salts. This coloration is ephemeral, passing to a port-wine tint, and finally disappearing.	7. Bleaching powder developes the characteristic *blue* tint (with some salts of aniline, *greenish blue*). The colour is ephemeral, soon passing to *wine-colour*, disappearing with an excess of chlorine.
8. Turns deep yellow with hydrochloric acid.	8. Turns deep yellow with hydrochloric acid.

These characters suffice, I think, to establish the identity of the principle contained in *Boletus luridus* and *B. cyanescens* with the artificial alkaloid *aniline* extracted from coal-tar. It is the first time that aniline has been shown to exist in nature.

The manner in which the blue colour is produced when the tissue of these *Boleti* is broken and exposed to the air is easily accounted for: I have shown in several of my former papers (*loc. cit.* p. 1) that when oxygen reacts upon organic matters in nature, it is generally in the state of ozone. The presence of some *ferment* in the tissue of plants, and in contact with the substance which combines with the oxygen, appears to be the cause of this remarkable modification of oxygen. Thus, when an apple is cut in two halves, the brown colour which ensues is owing to the action of ozone (as may be proved by directly applying the tests for ozone), and the ozone is produced by the influence of the ferment: for ordinary oxygen will not produce the coloration; and when the ferment is destroyed by boiling, the colour is not produced either. In the case of the *Boleti*, the aniline which exists in their tissue as a colourless salt, turns blue under the influence of ozone produced in contact with the ferment present in the fungus; for when this ferment is destroyed by boiling, no coloration ensues when the tissue of the fungus is broken and exposed to the air.

It is well known that some salts of aniline, when exposed for some time to the air, take a delicate rose-colour. This accounts for the beautiful rose tint not unfrequently remarked upon the stalks of those *Boleti* which contain aniline.

Analysis of the Diluvial Soil of Brabant, &c., known as the Limon de la Hesbaye. By T. L. Phipson, *M.B., Ph.D., F.C.S. &c.*

The curious geological formation known as the *Limon de la Hesbaye*, which extends from the Seine to the Rhine, traversing Belgium from east to west, where it covers the whole of the district of Hesbaye, a great part of Brabant, Hainault, and Flanders, is exceedingly remarkable for its fertility. "*It is to this deposit*," says D'Omalius d'Halloy, "*that we may attribute the richness of the most fertile countries of Belgium.*" It extends also over Picardy, stretching from the Seine to the other side of the Rhine, and is everywhere characterized by its great fertility and the excellence of the vegetable mould to which it gives birth by culture. No fossils have as yet been discovered in this deposit; it ranks among the "modern," "post-tertiary," or "diluvial" formations of geologists; and there exist, on different portions of the globe, similar modern deposits equally interesting in an agricultural point of view.

I have submitted this remarkable deposit to analysis, and its composition shows that though the Limon de la Hesbaye contains upwards of 90 per cent. of pure sand, yet the chemical ingredients necessary to form a fertile soil are present in it in notable quantity; besides which, its porosity, which allows water to pass slowly through it and admits the ingress of atmospheric oxygen, is an important condition of fertility.

When pulverized and exposed to the air, the Limon de la Hesbaye dries completely, but when in mass it retains its moisture for some time. When seen in mass it is brownish yellow, becoming of a lighter colour when dry, and giving a whitish-yellow powder when pulverized. Its density is about 2·00 (water=1·00); it has a straight fracture, possessing a certain compactness, though it can be pulverized in the hands without much difficulty.

The sample analysed by me was taken in the neighbourhood of Brussels: I was careful in selecting it from the centre of a stratification about 2 yards thick, and where it had never been submitted to cultivation. The result obtained is as follows:—

Moisture	traces
Organic matter and combined water	3·00
Ammonia	0·10
Potash, with a little soda	0·23
Lime	0·40
Magnesia	0·07
Alumina, with a little oxide of manganese	1·20
Oxide of iron	2·56
Phosphoric acid	0·20
Sulphuric acid Chlorine Carbonic acid	traces
Quartzose sand	92·24
	100·00

This composition resembles that of another deposit of *Limon*, equally remarkable for its fertility and the readiness with which it is converted into excellent arable land,—I allude to the celebrated *tchornoizen*, or black diluvial soil of the Ukraine, which has been analysed by several chemists; it extends from the Carpathian Mountains to the Urals, giving to the whole district included between these two ranges a characteristic fertility.

It is not my intention to discuss the geological origin of these deposits which are so important to agriculture, but I may state here that they are all post-tertiary formations, that they exist in several parts of the globe, and that the regions where they are present appear to be, in an agricultural sense, highly favoured by nature.

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On Hypobromous Acid. *By* Prof. H. E. Roscoe.

Professor Roscoe communicated to the Section the results of an investigation upon the lowest oxide of bromine, hypobromous acid, which had been made in the laboratory of Owens College, Manchester, by Mr. William Dancer. Balard in 1826 mentions the formation of a colourless bleaching salt formed by the action of bromine upon the alkalies, and since that date many chemists have indicated the presence of such a body, but it has not been prepared in a pure state or analysed. Mr. Dancer has succeeded in preparing the aqueous acid in a pure state, and has examined its chief properties and determined its composition. If bromine-water and nitrate-of-silver solution be brought together, one-half the bromine is precipitated as bromide of silver, whilst the other half remains in solution as hypobromous acid ($BrO\,HO$). The aqueous acid may be obtained by distillation at 30° C. *in vacuo*, but decomposes into bromine and oxygen at 100° C. The aqueous acid may likewise be prepared by shaking bromine-water together with oxide of mercury, and distilling *in vacuo*; in this case half the bromine forms the bleaching compound. Hypobromous acid unites with the alkalies, and forms salts analogous in smell and bleaching properties to the corresponding hypochlorites. Owing to the ease with which this compound splits up into bromine and oxygen, it was found impossible to prepare the hypobromous anhydride by any of the methods used for the isolation of the corresponding chlorine compound.

Description of a rapid Dry-Collodion Process. *By* T. Sutton.

A rapid dry-collodion process, by which dry plates can be prepared as sensitive as with wet collodion, has more than any other problem interested photographers. By the wet process, the negative has to be finished on the spot. The rapidity of this dry process depends upon the effect of bromine in dry collodion. In the Daguerreotype process a silver plate iodized is extremely insensitive, but when submitted to the fumes of bromine it is increased a hundredfold. In the wet, but not in this process, nitrate of silver is required, which is the element of instability. In preparing, therefore, rapid dry-collodion plates, bromo-iodized collodion must be used. But the image produced thus is extremely thin and superficial; it is therefore necessary to apply to the film a coating of some organic substance, in order to darken parts of the negative. Many substances have been tried for this purpose, but none produce so good an effect as gum-arabic. The paper concluded with the operations required for this process.

GEOLOGY.

Address to the Geological Section by J. Beete Jukes, *M.A., F.R.S.*

It is now thirty-two years ago since I first, when a "freshman" of this University, attended the geological lectures of Professor Sedgwick. I had previously had access to a cabinet of fossils, and had been accustomed to seek for specimens in my schoolboy rambles on the hills near Dudley. It may be imagined, therefore, with what interest I listened to the "winged words" of the Woodwardian Professor, which used day after day to delight an audience composed of all ranks of the University.

Geology and its kindred sciences did not then, indeed, form any part of our regular course of university studies, and many of the college tutors were so far from encouraging our attention to them, that they rather discountenanced it, considering them as at best useless and probably even dangerous pursuits. With such a man as Professor Sedgwick, however, in the Woodwardian chair, whose wit and humour delighted, while his eloquence aroused and informed his hearers, the love of the science and the knowledge of it could not fail to extend from one year to another.

The natural sciences are now considered as worthy of study, by those who have a taste for them, both in themselves and as a means of mental training and discipline. In my time, however, no other branches of learning were recognized than classics and mathematics, and I have with some shame to confess that I displayed but a "truant disposition" with respect to them, and too often hurried from the tutor's lecture-room to the river or the field, to enable me to add much to the scanty stores of knowledge I had brought up with me. Had it not been, then, for the teaching of Professor Sedgwick in Geology, my time might have been altogether wasted. But it was not only in the lecture-room that I learnt from him. With that kindness of heart and geniality of disposition which make him as much loved as his powers cause him to be admired, he was good enough to step down from his high place as a Professor of the University, and to take some notice of the young undergraduate whom he saw lingering over the trays of specimens when the lecture was over, to inquire his name, and to invite him to his table. He subsequently allowed me to accompany him on some excursions in different parts of England, and gave me some of those practical lessons in the field, which, as you know, teach more in three days than can be learnt in months or years in the museum or the lecture-room. I look back upon these circumstances as those which gave direction to the whole course of my life, and as the origin of a paternal friendship with which Professor Sedgwick has honoured me for so many years, and which it has been my chief pride to endeavour to deserve. I hope, Ladies and Gentlemen, I may be pardoned for these few personal allusions; but amid all the gratification which I must necessarily feel at the honour which has now fallen upon me, that, namely, of being called upon to preside, within the walls of my own Alma Mater, over the Geological Section of the British Association, it was impossible for me to neglect the opportunity of acknowledging the debt of gratitude I owe to one of the ruling spirits of both bodies, and of avowing that my chief claim to occupy this chair is that I am an old pupil of Professor Sedgwick.

One of the most obvious difficulties in the way of any person who now undertakes to preside over this Section is the thought of the contrast that will necessarily arise in the minds of many of you between him and his predecessors. That I am now occupying the seat that has been filled by Sedgwick, Buckland, Lyell, Murchison, Hopkins, De la Beche, Forbes, and so many other illustrious men, may well cause me to doubt my own capability of fulfilling its duties. One lesson I must certainly learn, and that is, to endeavour to make up for other deficiencies by attention and assiduity, and, above all, not to take such an advantage of the position, as to bring anything of my own before your notice, to the hindrance of others who may have something to produce that may be more worthy of it. At the end, then, of this Address, which I will endeavour to make as brief as possible, I shall consider my own mouth as almost closed for the remainder of the meeting, and shall endeavour so far to imitate the Speaker of the House of Commons as to say as little as possible.

I propose to take for my subject the external features of the earth's surface. The principal business of Geology is to acquire as accurate a knowledge as we can of the internal structure of the crust of the earth, and to learn as much as possible of all the operations by which that structure was originally formed, or by which it has been subsequently modified. The crust of the earth has always been receiving accessions to its composition, both from within and from without. In like manner it has always been subject to modifying influences proceeding both from within and from without. It is obvious that the external influences act directly upon the actual surface of the time being. It is equally obvious that the internal influences can only reach that surface by penetrating through the thickness of the crust. If, therefore, we ask by what means the present surface of the earth, or, to bring the problem within more narrow limits, by what means the present surface of any of our dry lands, has been produced, we should naturally conclude that it owes its form to the external influences that have been brought to bear directly upon it, rather than to the indirect action of those deep-seated agencies, which can only reach it through an unknown thickness of solid rock.

I believe this conclusion to be a true one. It is, however, by no means the idea which is commonly entertained, even by many geologists, while those who are not geologists are always inclined to refer all the more striking features of the surface

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of the earth to the direct action of convulsive force proceeding from the interior, rather than to their true source in the gentle, gradual, silent influence of the "weather," continued through an indefinite period of past time.

I have heard even educated men speak of the correspondence in the chalk cliffs of the opposite sides of the Straits of Dover, as evidence in favour of the notion that England had been separated from France by the tearing open of those straits by what they called some "great convulsion of nature." There is hardly a description to be found in any book, of any deep and narrow valley or mountain gorge—especially if the precipices on each side of it show entering and re-entering angles, and rocks that were obviously once continuous across the gap,—but what its formation is unhesitatingly attributed to this vague imaginary force, a "convulsion of nature." Nay, I have even heard the existence of broad valleys over an anticlinal arch, such, for instance, as the valley of the Weald, attributed to the effect of the gaping of the rocks at the surface, consequent on the upward flexure of the beds. Mythical powers of disturbance are called into existence with as bold a personification as the Βία and Κράτος of the poet, and with even less warrant for their existence.

It seems to me, therefore, that the time is come when geologists should study a little more closely this problem of the mode of production of the surface of the land, and determine exactly the method of the formation of those variations in its outline which we call mountains, hills, table-lands, cliffs, precipices, ravines, glens, valleys, and plains.

Few men, perhaps, ever pause to inquire into the origin of a great plain; nevertheless the question may well be put, and it is one which deserves an answer. Some plains are doubtless the result of original formation. They are level and flat, because the beds beneath the surface are horizontal. Even these, however, have very rarely a surface formed simply by the last-deposited beds. The actual surface is one that has been formed by the erosion and removal of more or less of the uppermost beds, and the production of undulations formed by the act of cutting down into the beds below. This erosion or denudation has even in many such cases gone to the length of entirely removing a much greater thickness than we should at first suspect, the present surface being one that has been laid bare by that removal.

In all cases where the beds below the surface are not strictly horizontal, or do not accurately coincide as to their "lie" with the form of the surface, it is obvious that the plain must be one of denudation.

Suppose we take the great plain on which we now are, and which stretches from Cambridge far into Lincolnshire. The hills which rise from it towards the east are formed by the escarpment of the Chalk, the beds of which terminate abruptly at that escarpment, and allow the clays which lie beneath the Chalk to come up to the surface and spread beneath the plain. The hills rising to the west of the plain, on the other hand, are formed of the Oolites, the beds of which lie below these clays and rise gently from beneath the plain, and themselves terminate in an escarpment still further west.

There can be no reasonable doubt that the whole thickness of the Chalk and the beds below it once spread many miles to the westward of their present boundaries. The little chalk-capped monticule of the Castle Hill, at the western end of the town of Cambridge, and the hills near Madingley show that the Chalk was once continuous that far, at all events, from the Gogmagogs; and, had still higher ground been left by the denudation still further west, that would in like manner have been capped by the bottom beds of the Chalk.

The hill on which Ely stands is, I believe, an outlier of the Lower Greensand, the general mass of which crops out some miles to the eastward; and other hills rising from the plain will in like manner be found to have their summits capped by beds, apparently horizontal, but in reality dipping at a very gentle angle to the eastward, so as to ultimately cut the surface of the plain in that direction and then sink beneath it. All such outliers are clear proof that the beds formerly extended over the intervening spaces, and show us that the rocks now left in the ground are only a portion of those that were originally deposited.

The great plain of the Fens, then, is one of denudation, its surface being one that is now bare in consequence of the removal from above it* of a thickness of many hundred feet of Chalk, and of other beds below the Chalk. But this reasoning may be carried out with respect to the whole of the flat lands of England and the British Islands. The great central plain of Ireland, for instance, stretching from Dublin Bay to Galway Bay, with an average elevation of less than 300 feet above the sea, has immediately beneath it abruptly undulating beds of Carboniferous limestone, rising up at all angles, and dipping in all directions. The most level parts of the surface sometimes cut horizontally across the most contorted and highly inclined beds. The small isolated hills scattered here and there about the plain are formed sometimes of beds of Old Red Sandstone that rise up from beneath the bottom of the Limestone, and sometimes of beds of Coal-measures which rest upon the top of it. It is here abundantly evident, then, that the internal forces of disturbance which have bent the beds from their original horizontality into so many curves, and broken them by so many dislocations, had nothing at all to do with the production of the present surface, which has been formed across all these bent and broken beds after the disturbances had ceased.

But, in fact, the very first glance at a geological map of a flat country, if there be two or more colours on it representing conformable groups of stratified rocks, is just as good a proof of this vast denudation as the most elaborate reasoning. The last-deposited group of beds would of course conceal all those beneath it; it would be represented by one uniform colour. Let the internal forces bend, or tilt, or break it in any fashion you like, they cannot of themselves remove a particle of it. It will still lie over all those on which it was originally deposited, and the map would show the one colour only, unless we go the length of supposing that a piece of the crust of the earth could be tossed over like a pancake, and laid down again with its bottom upwards.

I have taken the case of a plain in the first instance, because it is obvious that if we arrive at the conclusion that many plains are low and level because mountainous masses of rock have been removed from above their present surface, it will be easy for us to recognize the proofs of denudation in the hills and mountains, on whose flanks the obvious marks of it are still left.

A little reflection will show us that the outcrop of a bed is always a proof of denudation, for the present surface cannot possibly be the original termination, not only of that particular bed, but of all the beds above it. When then a succession of beds crop out rapidly one after another, as they always do in all hill-ranges and mountain-chains, we cannot escape from the conclusion that the existing surface has been formed by the removal of the former extension of the beds. This is the inevitable conclusion, whether the surface be horizontal and the beds below it inclined, or the beds be horizontal and the surface inclined, or the surface slope one way and the beds dip another, or there be any kind of discordance between the "lie" of the beds and the form of the surface of the ground. The only possible escape from this conclusion would be in the case where a succession of beds had been deposited on a slope, and had never been covered by any other deposit. This, however, is a case that could only occur in very recently formed rocks, and cannot apply to the outcrop of beds on the flanks of hills or mountains, where the surface of the ground itself has a high inclination.

In such situations the only escape from the conclusion that the surface was formed by denudation would be, proof that the undulations of the surface were exactly followed by the undulation of the beds below it, and, in fact, that the very same bed was everywhere found to be the one immediately below the surface.

If we except Volcanos or "Mountains of Ejection," all other hills and mountains are either caused by the removal of the rocks which once surrounded them, or have suffered from the removal of those that once spread over them. The first kind of hills have simply been left high, while the surrounding ground has been worn down to a low level about them. In the second kind, the rocks composing them have, indeed, been thrust up from beneath by internal force to a much greater elevation than those same rocks have in the surrounding area, and their height is due entirely to that upward tilting, vast masses of once superincumbent beds having been removed from above them. These hills are high, not in consequence of, but in spite of denudation. I have elsewhere proposed to call the first kind "*hills of circumdenudation,*" and the second "*hills of uptilting.*" To the latter class belong all the great mountain-chains of the world, and most of the smaller ones.

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* In this general statement the few feet of peat, or the little banks of drift gravel and sand which have been subsequently deposited on or grown over the plain, are, of course, disregarded.

It may be taken as an invariable rule, that, as we approach all mountain-chains formed by uptilting, the beds rise towards them, and end successively at the surface; lower and lower beds still rising up, until the lowest of all appear in the heart of the mountains, where they are often reared up into the loftiest peaks. True as is this general statement, it is only generally true. The great groups of rocks thus rise successively one from beneath another; but this general rise is often complicated by numerous folds and reduplications, by great longitudinal fractures, or by complex flexures.

The geological axis of a mountain-chain runs along the line where the lowest group of beds rises to the surface. The geographical axis may be said to run along that dominant crest which forms the watershed of the chain. But it by no means follows that these two axes are coincident, that the lowest group of beds is always confined to the line of watershed, or even that the loftiest peaks and summits rise from that crest. The geological axes are dependent solely on the internal forces of elevation; if, therefore, the geographical axes do not coincide with them, it shows at once that *they* are independent of those forces; in other words, that the great external features have not been caused by the direct action of internal movement. The position of the geological axes of mountain-chains has, however, been often erroneously placed, from the tendency to refer them to any great masses of granite or other plutonic rocks that may show themselves,—a reference which is more often erroneous than correct.

All mountain-chains of uptilting tell the same story, that if the internal forces of disturbance and elevation had acted alone, without any external action of denudation, and if they had acted without it to the same extent which they have with it (*supposing that possible*), the mountain-chains would have been many times more lofty than they are. I say "*supposing that possible,*" because it appears to me that the elevation of the lowest rocks might never have proceeded to the same extent, if the internal force had not been gradually relieved of some of the external weight which it had to lift. However that may be, we see now that the lowest beds which appear at the surface, about the geological axis of a mountain-chain, dip on either hand beneath an ever-increasing thickness of superincumbent rock, as we recede from the axis. All the rocks which have been affected by the same action of disturbing force must have stretched unbroken across the disturbed district, before the disturbance commenced; for the lowest rocks appear at the surface now, not in consequence of the flexure or fracture of those that were above them, but in consequence of their removal. That removal could not have taken place prior to the internal disturbance, unless we assume the existence of a deep hole or trough of erosion along the space where the mountain-chain was subsequently thrust upwards. The removal of the bent or broken beds, then, must have taken place either during the action of disturbance or subsequently to its termination. In either case it was an external action, the result, in fact, of moving water, which slowly wore away and carried off so many square miles or, as in some cases, so many hundreds or thousands of square miles of rock, so many thousands of feet in thickness. The internal forces operated simply by lifting up the rocks to within the region of the denuding influence, and they have only produced that indirect effect upon the features of the surface which results from their having brought up to different levels, and placed in various positions, masses of rock of various hardness and constitution, on which the forces of erosion and transport have had a corresponding variety of effect, when they reached them.

I believe that all our uptilted mountain-chains have thus grown by a very slow and gradual growth, the internal force thrusting upwards what the external agencies always tended to wear down.

The investigation of the nature and effects of the mechanical forces that have acted on the crust of the earth from the interior has been undertaken by many eminent philosophers, by none with more acuteness and profundity than by our present General Secretary, Mr. W. Hopkins, who is so distinguished an ornament of this University. To the correctness of the mathematical reasonings employed in these researches no exception is of course to be taken, even by those who may withhold their assent from some of the conclusions arrived at. I profess my incapacity to engage in the discussion of mathematical problems. Nevertheless, it has sometimes occurred to me to suppose that, however sound and legitimate may be the conclusions thus drawn from the premises assumed, they may still be imperfect or inadequate as conceptions of the truth, in consequence of the incompleteness of the assumptions on which they are based. I shall not venture, even by a guess, to attempt to supply this defect. I only wish to regard the question as still an open one, thinking it possible that some condition or some agency may have been hitherto omitted from the speculation, of which no one has as yet, perhaps, formed even a conception. The researches already made may be admirable guides in all future investigations, and most useful in clearing the way for them; but it may nevertheless be dangerous to take the conclusion as so far established as to render future investigation unnecessary.

There is one line of research, however, in pursuing which we may feel sure of the ground on which we tread, and that is the observation of occurrences which take place before our eyes, and of structures which each one may see and examine for himself.

We have, in Earthquakes and Volcanos, the external symptoms of the action of the earth's internal forces. What they do now, we may feel sure they were able to do formerly; and we have no right to assume that they ever did either more or less within a given period than they have done during historic times.

Volcanos drill holes through the crust of the earth, and eject lava and ashes through these holes. These holes are often arranged in lines, as if they were connected with linear cracks in the earth's crust.

Earthquakes jar and shake the earth's crust, throw its surface into transient waves, and cause sometimes cracks and open fissures to appear at that surface. The largest of these fissures, however, are rarely more than a few miles in length and a few yards in width, and they appear rarely to leave any permanent traces on the surface, or to give rise to any of its more striking features. No one has ever yet pointed to any valley or any glen, still less to any river-course, as having been entirely caused by the gaping of the surface during any known earthquake, and independently of subsequent erosion by running water.

Mr. Mallet's researches have given us the means of calculating the depth at which the impulse of an earthquake may originate. This depth seems to be always proportional to the extent of the surface affected, from which it is obvious that in many cases a very considerable thickness of the external envelope of the earth must have been traversed by these movements. Supposing them to have a local origin, and to be caused by, or to be accompanied by, any considerable disturbance, either of flexure or fracture, in the solid or quasi-solid rocks at or about the centre of origin, it seems necessarily to follow that the amount of disturbance must lessen as we recede from that centre, in proportion to the thickness and extent of the matter over which it is diffused. The tremblings and undulations, then, and the surface-cracks and fissures produced by earthquakes are probably only the slight external indications of more intense but more local disturbance below. Great open fissures and gapings of the surface could only, as it appears to me, be caused by disturbances originating at a comparatively slight depth, where it is difficult to imagine any cause for them, and where, as a matter of fact, *great* disturbances never do seem to originate.

In addition to the more convulsive movements of the shocks, permanent elevation and depression of the surface take place during earthquakes, and also to an equal if not greater extent by a slow gradual movement, unaccompanied by earthquakes, and therefore not perceptible to our senses. These risings and sinkings of the surface are evidently the result of the upward or downward movement of the whole thickness of the earth's crust, whatever that thickness may be.

Resting on considerations such as these, thus hastily sketched out, I am inclined to be bold enough to dispute the physical possibility, or at all events to deny the actual occurrence, at any time, of such surface manifestations of internal force as could give rise to what have been called "*craters of elevation*," "*valleys of elevation*," or any other large openings of the surface of the ground. I would go even further than this, and hesitate to believe that any high inclination or great contortion had ever been imparted to any beds at, or close to, the surface[*]. I believe all such disturbed positions to have been acquired by a slow creeping movement, the result of the combination of great force acting against almost, but not quite, equally great superincumbent pressure, and therefore at a correspondingly great depth, and that, by the very constitution of the interior of the earth, such great force could not be brought to bear upon any mere point or line of the surface.

The rocks thus disturbed ultimately arrive at the surface, because they have been laid bare by the stripping off of veil after veil of covering, by the external erosive forces acting over the upraised area—upraised either during the disturbance, or by a subsequent action of elevation of a broader and more equable character. These same combined actions, still further carried out, ultimately bring to the surface the Metamorphosed Schists, which had been deeply buried by the converse actions of depression and deposition, as well as the granitic masses, which, proceeding from the interior, slowly worked their way upwards to a certain height, but cooled and consolidated before they were able to approach the surface as it existed at the time of their intrusion.

No one can study a mountainous district, in which the rocks have been greatly bent and broken, with the same care and attention that has been bestowed by the Geological Survey on the mountains of the British Islands, without perceiving that the external features, whether of hill or valley, do not depend on the frangibility of the rocks, but on their relative power of resistance to erosive action. The hard siliceous rocks, or those best adapted to resist the chemical and mechanical action of water, form the prominences; the softer or more soluble rocks form the valleys and low grounds. The upward or anticlinal curves in the beds, over which, if anywhere, external gaping fissures would be formed, are at least as often marked by the occurrence of hills and ridges over them as of valleys, the external feature depending altogether on the "weatherable" nature of the rock.

The same reasoning is applicable to great faults and dislocations. We are all familiar with the fact that, of faults that have a dislocation of hundreds or even thousands of feet, there is often not the least indication at the surface of the ground, which may be a perfect plain, or may undulate, without any regard to the subterranean structure of the rocks. This seems to me to be strong evidence in favour of the supposition that these dislocations never did make any great feature at the surface. The amount of dislocation has been gained foot by foot and inch by inch below, the movement being so slow as to allow of the surface-irregularity being always diminished or obliterated as fast as it was formed. If a great dislocation had taken place at once, and an equally great cliff had been formed by it, surely the traces of such a feature would have been more often preserved than they are.

Small cliffs do occur sometimes along the line of a fault, but only when it so happens that at the present surface of the ground a hard unyielding rock is brought against a soft and more perishing one; and the cliff or bank is always in proportion to the "weatherable" natures of the two rocks, and not to the amount of the dislocation. In like manner, valleys sometimes run along the line of faults, and especially of large faults, and there is sometimes a sort of proportion between the magnitude of the dislocation and that of the external feature; but even in these cases the magnitudes are not of the same kind, the width of the fault being very slight indeed as compared with the width of the valley. The coincidence is one of direction only, the original fracture having determined the direction of the subsequent erosive forces, so as to cause them to excavate the valley along that line rather than any other.

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[*] The contortions in the Chalk and the glacial Drift described by Sir C. Lyell, from Messrs. Forchhammer and Pugaard, as occurring in the Island of Möen in Denmark, show that this belief must be somewhat modified, and that local flexures and fractures do sometimes take place even at the surface. If so, then some of those apparent in the Alps and other recently formed mountain-chains may have also taken place at or near the surface. It is, however, demonstrable in all these cases that subsequent denudation has acted upon these areas, though the amount of matter removed may not be so great as the expressions in the text would imply.

When, moreover, we examine faults below ground, we find no trace of any wide-gaping fissures; the walls of the fault, on the contrary, are jammed tightly against each other, and show frequent evidence of immense grinding force, proving the friction of the sides to have been enormous. In hard massive rocks there doubtless occur open spaces here and there between the walls, "pockets" or "bellies" between their projecting protuberances, or where they have been partly kept asunder by fragments detached from the sides. These are often full of crystalline minerals, and form "mineral veins" below, but seldom, if ever, form valleys or ravines at the surface.

If these ideas as to the relative action of the internal and external forces at work upon the crust of the globe be well founded, it follows that none of the present features of the surface of the globe have been produced by the direct action of the internal forces, except volcanic orifices and cones, and that all others have been produced by the process of external erosion, except such as have been formed by external deposition, like hills of blown sand or alluvial flats and deltas.

The surfaces of our present lands are as much carved and sculptured surfaces as the medallion carved from the slab, or the statue sculptured from the block. They have been gradually reached by the removal of the rock that once covered them, and are themselves but of transient duration, always slowly wasting from decay. Even, then, if the internal forces could produce such external features, it can always be shown that the surface which existed when they operated has long since disappeared, together with, in many cases, vast thicknesses of rock that intervened between it and the present one.

It remains to say a few words on the nature of the erosive agencies which form these surfaces.

The ocean is the grandest of these. The ceaseless breaking of its waves against the margin of the land constantly gnaws into and undermines it, and the tides and currents carry off the eroded materials and deposit them on some part or other of the ocean-bed. This action is that of a great horizontal planing-machine, always tending to the production of level surfaces, the cutting power being confined to the sea-level, while the matter carried off tends to fill up the hollows of the inequalities that lie below it. The denuding action of the sea, therefore, produces "plains of denudation" on the parts it has passed over, and long lines of cliffs or steep banks along the margin where its influence ceased. It is essential for the energetic action of the sea that it should be the open sea, where a heavy swell can roll in upon the land, and where gales of wind can hurl furious waves against it. In sheltered bays and narrow inlets and fiords its erosive agency becomes comparatively small, and in very protected places sinks to nothing.

While, then, we look to marine denudation as the cause of wide plains, of long escarpments, of bold headlands and isolated hills, and of the general outline of mountain-chains, and as the remover of the great groups of rock that were continuous over the area of the mountains before their elevation was commenced, I believe we err when we attribute to that cause the lesser features by which these greater ones are themselves modified. The river valleys that traverse the great plains, the gullies that run down the sides of the hills, the valleys, glens, ravines, and gorges that furrow the flanks of the mountain-chains, have, I believe, all been caused by atmospheric agency on the land, while standing above the level of the sea.

The only case in which the sea tends to produce anything like a valley is that in which it forms open sounds or straits between islands, where the set of the tides and currents imparts to it a river-like action. Those depressions in the crest of a mountain-chain which are called "passes" or "gaps" have doubtless been often caused by this action, but it is obvious that this ceases as soon as the summit of the pass once rises above the sea-level and prevents the currents from sweeping through it.

While the ordinary erosive action of the sea is a horizontal one, tending to the production of plains bordered by cliffs, that of the atmospheric agencies is a vertical one, always tending to the production of furrows, or more or less steep-sided channels, on all the land exposed to their influence.

Rain falls vertically, and tends to sink vertically into rocks, producing decomposition in them, both by mechanical and chemical action. A superficial coating of greater or less thickness is always thus kept in a state of decay.

In almost all granite districts, the rock beneath the hollows and flatter parts of the ground will often be found to be decomposed *in situ* to a mere sand, so that it could be dug out with a spade to a depth of several feet. Roundish lumps are found here and there in this sand, which were the centres of the original blocks; these, as well as the solid rock below, showing every gradation of firmness, from hard crystalline rock to a mere incoherent sand. I have observed this in granite districts in all parts of the world, and was much struck with it during the past summer in the southern part of Brittany, where the deep narrow lanes often showed both granite and gneiss thus rotten and soft, to a depth sometimes of fifteen or twenty feet. On the steeper slopes the exposed rock was much less decomposed, obviously because the particles had been washed down and carried off as fast as they became completely disintegrated.

Hard limestones, again, exhibit the effects of the action of the rain in the numerous open fissures and caverns that are always found in them, the water here having dissolved the rock and carried it off in solution, as if it were so much salt or sugar. The fantastic forms and honeycombed surfaces of all limestone crags attest the same action. In baring the surface of a limestone quarry where the beds are inclined at any considerable angle, they are often found to be furrowed by rain-channels one or two feet in depth and several inches in width, the hollows being filled with the finest earth. A deep covering of mould and turf is no protection against this action, and perhaps even aids it by contributing an additional dose of acid to the rain-water.

Even where hard siliceous rocks exhibit a weathered coat of a very slight depth, a mere skin perhaps of a quarter of an inch thick, as is the case in some Felstones, still it merely proves that the atmospheric influences cannot affect a great thickness at any one time, and does not render it impossible that many such weathered coats may have been formed outside the present surface, and successively removed altogether by the completion of the process.

The joints of rocks when first formed are doubtless mere planes of separation, without any interstice that would allow the insertion of even the thinnest edge of a knife; they would be quite insensible to the sight, and would perhaps scarcely of themselves be sufficient to cause the separation of the rock into distinct blocks. In working deep mines it is sometimes said that the rocks cease to show any joints at all. The joints, however, doubtless exist, although they are invisible, while the open joints, such as we see in all rocks near the surface, have been opened by the "weather" acting along these concealed planes of separation.

The action of the atmosphere, then (*i. e.* the chemical action of air and water and the various gases mingled with them, and their mechanical action, owing both to their movements of gravity and their expansion and contraction from changes of temperature), is operative in the gradual destruction of rock, to a much greater vertical depth beneath the surface than is commonly recognized. Its superficial action is still greater, and has also, as I believe, generally failed, as yet, in receiving due appreciation. The rain that falls upon the surface and does not sink beneath it runs, of course, down the shortest and steepest slopes it can find, and is collected first into rills, then into brooks and rivulets, and finally passes by rivers to the sea. This superficial drainage of a country is often augmented and kept up by springs, which are caused by that part of the water that had sunk beneath the surface finding its way back to it.

The natural tendency of running water is to cut its channel deeper, and that at a rate compounded of the rapidity of the current and the nature of the rock below. Let any one take the basin of drainage of any great river, and trace it up to its source, following all its tributaries to their sources, and he will not fail to perceive that all the varied features of the different channels of this system of running waters are the result of these two circumstances only. In the mountain glens he will see those that traverse granite commonly with rounded open forms; those that cut through hard slates, or thick horizontal sandstones, are commonly narrow and precipitous, with jagged cliffs and overhanging ledges, perhaps, jutting from the sides of the ravines. He will see the marks of the old cataracts that once fell over these ledges, but which now are removed to other places, or converted into mere rapids, or perhaps altogether obliterated by the cutting down and cutting back of the streams. Torrs and pinnacles will be left here and there, perhaps, rising up from the bed of the stream, showing the former islets and rocks which resisted the erosive action better than the parts on each side of them. Where a softer and more yielding mass of rock occurred, there the glen widens into an open valley; the narrowest and most jagged and steep-sided glens are just where the rocks are most hard and intractable, and best calculated for resisting the chemical and mechanical action of running water.

The scale upon which these operations have been carried out does not affect the nature of the argument. The action has been the same in the miniature glens of our own mountains and in the grander and more awful abysses that gash the sides of the Alps, the Andes, and the Himalayas.

In all cases when the river comes down now, or has formerly come down, in the form of a glacier, before springing into running water, the ice-mass has of course scooped out and deepened and widened the valley in its own peculiar fashion.

When we leave the mountains and come down into the lower lands, where the rivers wind with a more gentle stream from side to side of broad open valleys, through wide alluvial flats, still it is to the river that the present form and depth of the valley are due. Whatever may have been the undulation of the original surface of marine denudation which determined the course of the primary stream, the river has long since cut down beneath that surface, and is still occupied in cutting deeper, so long as it retains any sensible current at all. It effects this by undermining the bank now on one side and now on the other side of the valley, shaving off a little corner here and another there, so that a river not a hundred yards broad, perhaps, may eventually form a valley of several miles in width. The obstructions it accumulates from time to time in its own bed constantly deflect its channel, so that ultimately it visits every part of the valley.

In many cases the mere deepening of the valley may necessarily widen it also, since the rocks may be of such a composition, or may lie in such a way, as not to be able to form a bank of any steepness; and the materials, therefore, always slip down towards the bottom of the valley as fast as their bases are cut into.

It is true that all these processes are infinitesimally slow; but if carried on through a period of time indefinitely great, it is obvious that it is impossible to assign a limit to the amount of their results.

I have for several years been studying the origin of the river-valleys of the South of Ireland, and have, since the last meeting of this Association, been compelled to arrive at the conclusion that the great limestone plain of the centre of Ireland has lost a thickness of 300 or 400 feet at least, by the mere action of the rain that has fallen upon it. As a corollary of this conclusion, I have also been led to perceive that the longitudinal and lateral valleys of the Irish mountains—and if of them, then those of all other mountain-chains of the world—are the result of the action of the water or the ice that has been thrown down on them from the atmosphere.

If we take any mountain-chain and its adjacent lowlands, and suppose no rain to fall upon them for a time, and that all the valleys of whatever description were filled up, and the sides of the mountains smoothed over from their peaks to their bases, I believe the surface thus produced would be one representing the limits of marine denudation; then let rain begin to fall on such a country, and all the elaborate structure of valleys, gorges, glens, and ravines would be produced by it.

I believe that the lateral valleys are those which were first formed by the drainage running directly from the crests of the chains, the longitudinal ones being subsequently elaborated along the strike of the softer or more erodable beds exposed on the flanks of those chains. I do not, of course, intend to say that any country ever existed without valleys, since valleys of some kind must commence as soon as the first peaks of the mountains show themselves above the sea, and must be continued and extended in proportion to the extent of the land which gradually rises into the atmosphere. Atmospheric denudation and marine denudation have always been at work simultaneously upon the different parts of every land in the globe, and their action may be very complex, so that it is often difficult or impossible to separate the results of one from those of the other at any particular place. Still I believe we may generally regard the external form of a mountain-chain as due to marine, and the valleys within it as the result of atmospheric erosion.

Most of you will be aware that the views I have thus endeavoured to place before you are not altogether original; other persons have before now proposed the same method of explanation of the form of ground. M. Charpentier long ago referred the origin of the valleys of the Pyrenees to the action of the rivers which traverse them. Mr. Dana had pointed to the same action as the cause of the wonderful system of ravines that furrows the sides of the Blue Mountain range in New South Wales, and of the deep ravines separated by knife-edged ridges which radiate from the centres of the high islands of the Pacific. I confess, however, that I had, up to the present year, hesitated to accept this explanation without reserve; and therefore, since I am now convinced of its truth, I am anxious to take the earliest opportunity of recording that conviction*.

Mr. Prestwich, in his recent papers read before the Royal Society, has adopted the hypothesis of the subaërial deepening of the valleys of the Somme and the Seine, and other river-valleys both in France and England, to account for the formation of the freshwater gravels which he finds on the flanks of those valleys, so high above the present levels of the rivers or of any possible floods.

Professor Ramsay has in like manner attributed the formation of the hollows in which the lakes of Switzerland lie, to the ploughing action exercised on the subjacent rocks by the action of the glaciers, when far more extensive than now. The formation of lakes lying in "rock-basins," and not formed by the mere stoppage or damming up of a river, had always been a complete puzzle to me until I read Professor Ramsay's paper in the last Number of the Geological Journal (May 1862). I believe his explanation of their origin to be the true one.

That he and Mr. Prestwich and myself should all, within the space of the same twelvemonth, have been compelled to appeal to external atmospheric action as the only method of explaining the origin of the different surface-phenomena we were studying, is of itself, I think, good evidence that we are all three pursuing the right track in our search after truth.

At the instant of penning this sentence, I see by a newspaper paragraph that Dr. Tyndall follows us in his speculations as to the origin of the valleys of the Alps†.

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* Had I not become previously convinced of the extent and power of atmospheric and river action in consequence of my own observations, all scepticism must have yielded to the proof of it detailed in the admirable Report by Dr. Newberry on the Geology of the Colorado River of the West, published by the United States Government at Washington in 1861. It was only in February 1863 that I saw this work through the kindness of Dr. Newberry, who himself transmitted to me a copy of it. The beautiful maps and plates and the numerous woodcuts illustrate the text in a way that puts to shame the miserable niggardliness of our own Government in such matters; for here they are either committed to the red-tape ignorance of mere clerks whose duty it is simply to curtail expenditure, or to the equally uninstructed indifference of higher officials in dread of the well-meant but blundering questioning of some man of figures in the House of Commons, or still oftener left to the enterprise of some publisher, who has of course his profit to make out of the work. An advertisement at the beginning of the American Report shows that the Senate of the United States ordered ten thousand extra copies of it to be printed, five hundred of which were given to the officer commanding the expedition.

Dr. Newberry shows in his Report that the wonderful *cañons* which traverse much of the country of California, and some of which are from 5000 to 6000 feet deep, and only wide enough for the waters of the rivers to flow through them, have been cut down by those rivers through horizontal and quite undisturbed beds belonging to the Carboniferous, Devonian, and Silurian periods into the Granite below, and moreover that wide valleys in other parts have also been excavated by the gradual action of atmospheric erosion, leaving numerous perpendicular torrs, crags, or pinnacles of rock here and there, all showing the same horizontal beds.

† A subsequent reading of Dr. Tyndall's paper, and of a notice of it afterwards by Professor Ramsay, showed me that Dr. Tyndall was inclined, at the time of writing it, to attribute the Alpine valleys too exclusively to the action of glaciers. The valleys must have been commenced and many of them almost completed before the glaciers, although the

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As a concluding observation, allow me to remark how curiously the threefold physical agencies that are in simultaneous operation on the crust of the globe were typified in the old heathen mythology. The atmosphere which envelopes the land and rests upon the sea, the ocean which fills up the deeper hollows of the earth's surface, and the nether-seated source of heat and force that lies beneath the crust of the earth are each personified in it as a great divinity. If one of the old Greek poets were to revisit the earth, and clothe these ideas in his own imagery, he would tell us in sonorous verse of Zeus (or Jupiter), the God of the Air, ruling all things upon the land with his own absolute and pre-eminent power; of Poseidon (or Neptune) governing the depths of the ocean, but shaking the shores which encircle it; and of Hades (or Pluto), confined to his own dark regions below, tyrannizing with all the sternness of a force irresistible by anything which can there oppose it, but rarely manifesting itself by any open action within the realms of the other divinities.

On an Early Stage in the Development of Comatula, *and its Palæontological Relations. By* Professor Allman, *M.D., F.R.S.*

The subject of this communication was a small Echinodermatous animal, a single specimen of which was obtained by the author on the south coast of Devon, where it was found attached to one of the larger Sertularidæ, dredged from about four fathoms' depth. The author regarded it as one of the early stages in the development of *Comatula*, and though quite distinct from the well-known *Pentacrinus* stage of this crinoid, believed that it had been witnessed both by Thompson and Dujardin, but not correctly described or figured by either of them. It consisted of a body borne upon the summit of a long jointed stem. The body had the form of two pyramids placed base to base. The upper pyramid is formed of five triangular valve-like plates, moveably articulated upon the upper side of the lower pyramid, and capable of being separated from one another at the will of the animal, so as to present the appearance of an expanding flower-bud, and again approximated till their edges are in contact and the original pyramidal form restored. From between the edges of these plates, long flexile tentaculoid appendages, which must not be confounded with the permanent arms of *Comatula*, are protruded in the expanded state of the animal, and within these is a circle of shorter, more rigid, rod-like appendages which seem to be moveably articulated to the upper side of the calyx, immediately round the centre, where it is almost certain that the mouth is placed. The lower pyramid or proper calyx is mainly formed of five large hexagonal plates, separated from the summit of the stem by a zone, whose composition out of distinct plates could not be demonstrated, and having five small tetragonal plates intercalated between their upper angles. In assigning their proper value to the several plates thus entering into the body, the author regarded the lower zone, which rests immediately on the stem, as simply a metamorphosed joint of the stem itself, while the verticil of plates, situated immediately above this, is the true basilar portion of the calyx. The five small intercalated plates are the equivalents of the *radialia*, and destined to carry afterwards the true arms of the crinoid; while the five triangular plates which constitute the sides of the upper pyramid are *interradialia*. Professor Allman considered the little animal described in this communication as of special interest, in the light which it seemed capable of throwing on the real nature of certain aberrant groups of *Crinoidea*, such as *Haplocrinus*, *Coccocrinus*, &c., in which the calyx supports a more or less elevated pyramidal roof, composed entirely or in great part of five triangular plates, which find their homologues in the five sides of the pyramidal roof of the little crinoid which formed the subject of his paper.

On Bituminous Schists and their Relation to Coal. By Professor Ansted, *F.R.S.*

The occurrence of rocks of all geological periods, and in most parts of the world, containing a sufficient quantity of the mineral hydrocarbon to be worth distilling

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present depth, width, and regularity of many of them are doubtless ascribable to glacier action.

for various economic purposes is well known; and there are certain cases in which there is an apparent passage from the shale or schist containing so large a quantity of these mineral oils as to burn like fuel, into true coal, which also sometimes contains a large quantity of hydrogen, and can be distilled for some purposes with advantage. The chief object of this paper was to direct attention to some of the rocks known among geologists as bituminous schists.

Two deposits of this kind have long been known in France, and have recently been visited by the author,—one between Nantes and Rochelle, in the Bourbon-Vendée, the other near the town of Autun. The former are called the Feymoreau schists, and they were distilled with success in 1830 for paraffine oil, other light burning oils, and lubricating oils, by the method since patented by Mr. Young. Owing to the absence of means of communication, the works were suspended; and afterwards M. Selligué, the inventor of the process, carried on similar operations with greater success near Autun, where there is now a very large manufacture of light oils and paraffine.

The Feymoreau schists resemble in appearance the rich Torbane Hill mineral of Scotland, and resemble both that and Boghead coal very closely, but they cannot be used as fuel; they only yield about 15 per cent. of light oils. They are very thick, but do not extend far in a horizontal direction. They underlie the coal-measures, or rather the productive part of the measures, and almost represent the underclay of a poor coal-seam. In this respect also they resemble the Scotch bituminous shale.

The Autun schists occur considerably above the highest seam of coal in the coal-measures. They are quarried or obtained from drifts. They are thick shales, bearing no resemblance whatever to coal, and not in any way capable of being used as fuel. The best varieties yield 50 per cent. of oils of all kinds, but others are very poor. They are moderately rich in paraffine.

The shales of the paper-coal, near Bonn, on the Rhine, are also used for distilling, and paraffine is made from them; they have no resemblance whatever to coal, and could not be mistaken for it. The lias-shales (*Posidonia-schists*) in many parts of Germany are also distilled for the light oils and paraffine, with some success.

Bituminous schists of all geological dates, some passing into coal and others hardly distinguishable from common clay, thus exist in many parts of the world, and all agree in the one important point, that they may be used for obtaining certain valuable products by special treatment. "It is important," the author concluded, "that such substances should be recognized as a class, and not mixed up with or mistaken for coals, and that there should be some understanding among scientific and practical men what coal is, and in what it differs from certain minerals containing hydrocarbons sometimes associated with it."

On a Tertiary Bituminous Coal in Transylvania, with some remarks on the Brown Coals of the Danube. By Professor ANSTED, *F.R.S.*

The deposits of mineral fuel on and near the Danube are, for the most part, lignites or brown coal. These are extensive, and have been much used. The fuel burns freely, and can be employed for all purposes; but it has two faults. It contains a large percentage (averaging 15 per cent.) of hygroscopic water, and it falls to powder on exposure to air, especially in changeable weather. It is uneconomical, and cannot be stored. These deposits are newer Miocene; they occur in and with sands not converted into sandstone, and marly clays not shales. They are generally in lenticular masses, unconnected one with another.

These lignites do not occur in the smaller mountain-valleys of the Carpathians. In their place, in the Zsil valley, is a disturbed deposit, also tertiary, and also containing mineral fuel; but the fuel is here an excellent bituminous coal, and not a brown coal. There are twelve well-defined workable beds, one of them varying from 30 feet to 50 feet thick, four others 5 feet to 10 feet, and the rest smaller. They are associated with good hard coal-grits, shales, and ironstone bands. Two of the coal-beds are well marked by an overlying bed of fossil shells (a species of *Cerithium*).

All these coals are nearly free from hygroscopic water, and stand exposure for years without injury. They have been examined by the authorities at the Geological Institute at Vienna, and found to consist of carbon 57·8, ash 6·5, water 2·1, and the carbonic unit is stated at 5582. This is equal to the average of Austrian bituminous coal, and very much superior to the average of brown coal. There is no doubt of the tertiary origin of the Zsil coal. The beds containing it have, however, been much altered and broken, and since covered by unconformable tertiary rocks of newer date. Above these again is a thick gold-alluvium.

In conclusion, the author drew attention to the fact that coal, like salt, is limited to no geological period, and required no high temperature either to elaborate the plants of which it was made, or to complete the conversion of the vegetable matter into coal. There is no volcanic district at all near the locality in which the Zsil coal occurs. There is no underclay beneath the Zsil coal, nor is there beneath the Liassic and Cretaceous coals, somewhat extensively worked on and near the Danube or in the Carpathians. These coals have therefore, in all probability, been formed of transported vegetable matter. The presence of a true bituminous coal of economic importance in a geological position hitherto limited to lignite, the author submits as a fact too important to pass without being placed on record.

On the Glacier Phenomena of the Valley of the Upper Indus.

By Capt. GODWIN-AUSTEN, *24th Regiment.*

The glaciers noticed in this paper are supposed to be of greater extent than any yet known; they occur in that part of the great Himalayan chain which separates Thibet from Yarkund, in E. long. 76°, and N. lat. 35–36°, and extend over an area about 100 miles from east to west, from Karakorum Peak, No. 2 (28,265 ft.), to the Mountain of Haramosh.

The glaciers which supply the Hushé River, which joins the Indus opposite Kapeloo, were first described. Those of the upper portion of the valley take their rise on the southern side of the Peak of Masherbrum, and are about 10 miles in length.

The Great Baltoro Glacier takes its rise on the west of Gusherbrum Peak; on the north it is joined by a great ice-feeder which comes down from Peak No. 2; opposite to it, from the south, is another; both of these extend 9 or 10 miles on either side of the main glacier. This, from its rise to its further end, measures 30 miles; its course is from E. to W.; the breadth of the valley along which it flows is 12 miles. It receives numerous tributaries along its course, some of which are 10 miles and more in length; two of them, on the N., lead up to the Mūstakh Pass into Yarkund (18,000 ft.), whence a glacier descends to the N.E., about 20 miles in length.

The Nobundi Sobundi glacier takes its rise from a broad ice-field which lies to the N. of lat. 36°, and has a S.E. course for 14 miles, with numerous laterals; it then turns S., when it bears the name of the Punmah Glacier; about 5 miles from the termination it is joined by a glacier from the N.W., 15 miles in length.

The Biafo Glacier is perhaps the most remarkable of any of this part of the Himalayan range; it has a linear course of upwards of 40 miles; the opposite sides of the valley are very parallel along its whole length, and the breadth of ice seldom exceeds a mile, except where the great feeders join it from the N.E.

From the summit-level of the Biafo Gause a glacier is continued westward to Hisper in Nagayr, 28 to 30 miles in length.

The Chogo, which terminates at Arundoo, takes its rise between the Mountain of Haramosh and the Nūshik Pass; it is about 24 miles in length, with numerous branches from Haramosh, 8 miles in length.

The waters from all the glaciers, from that of Baltoro in the E. to Chogo in the W., are collected into the Shigar River, which joins the Indus at Skardo.

All these glaciers carry great quantities of rock-detritus. The blocks on the Punmah Glacier are of great size.

The author next described the groovings and old moraines of a former extension of the glaciers in this region, showing that they reached many miles beyond their present terminations, and rose upwards of 400 feet above their present levels. The paper also described the thick alluvial accumulations of the valley of the Indus, particularly those of the neighbourhood of Skardo.

On a New Species of Plesiosaurus *from the Lias near Whitby, Yorkshire.*

By Dr. A. Carte, *F.L.S., and* W. H. Baily, *F.G.S.*

The very large and perfect *Plesiosaurus*, the description of which formed the subject of this communication, was discovered in the Lias at the Kettleness Alum-pits, near Whitby, on the 27th of July, 1848, and presented by the Marquis of Normanby to the late eminent Surgeon, Sir Philip Crampton, as a mark of regard for his scientific attainments, who, in accordance with the anxious desire he always felt for the advancement of science, bequeathed it to the Royal Zoological Society of Dublin, in whose Gardens it was first exhibited to the public in May 1853; that Society, with the same object in view, has now deposited it in the Museum of the Royal Dublin Society, where every facility is offered for the study of this magnificent and largest example of the genus known. The total length of this skeleton (of which a drawing of the natural size was exhibited), measured in the line of its vertebræ, is 22 ft. 5 in. It lies in very nearly a natural position, resting upon the ventral surface, with the head and neck slightly inclined towards the right side; the head, with the under jaw, is in a good state of preservation, and, being freed from the surrounding matrix, the principal bones composing it may be easily recognized; the vertebral column has throughout its entire length fallen over towards the right side, presenting a slight irregular curve; it exposes in the cervical series a side view of the *centra* or bodies of the vertebræ, with their large neural spines (*neurapophyses*), and in some instances remains of the cervical ribs or hatchet-shaped bones (*pleurapophyses*), the bodies of the dorsal vertebræ being almost entirely concealed, the massive ends of the neural spines and transverse processes projecting prominently above the general surface. The caudal portion of the vertebral column is somewhat dislocated and thrown out of position, especially near its junction with the sacrum; the bodies are, however, in some cases well exposed, with their spines and processes. The ribs, thirty in number, are spread out on either side of the dorsal vertebræ, those of the left side being almost in their natural position. The anterior paddles are extended from both sides, on a plane nearly at right angles with the head and neck, the right posterior paddle stretching out in a direction parallel to the anterior, that on the left side inclining more towards the tail; in this paddle the tarsal bones, with their phalanges, are deficient, that portion having been unfortunately carried to the calcining-heap before it was observed.

The following are some of the principal measurements of this species, which it was proposed to call *Plesiosaurus Cramptoni*.

	ft.	in.
Total length of skeleton	22	5
Length of the skull from the point of the premaxillaries to the parietal crest	2	11
Length of the lower jaw, from the symphyses to the extremity of the angular piece	3	10
Breadth of lower jaw across the tympanic condyles	1	10½
Breadth of skull across the orbits	1	3
Breadth of skull across the snout	0	6
Height of skull at posterior end, from angular piece of lower jaw to parietal crest	1	1
Height at extreme point of snout	0	5
Length of cervical portion of vertebræ, twenty-seven in number	6	0
Length of dorsal and lumbar, thirty in number	8	0
Length of caudal, about thirty-four (some of the terminal vertebræ being deficient)	5	6
(Total number of vertebræ which can be counted ninety-one.)		
Length of humerus	1	9
Breadth of humerus at radial extremity	0	10
Length of radius	0	6
Breadth of radius at proximal extremity	0	5
Length of ulna	0	6½
Breadth of ulna at proximal extremity	0	4½

	ft.	in.
Length of femur	1	10
Breadth of femur at distal extremity	0	10½
Length of tibia	0	6½
Breadth of tibia	0	5
Length of fibula	0	6
Breadth of fibula at femoral end	0	6

The proportion of the head to the neck, measuring from the point of the superior maxillary to the extremity of the angular piece of the lower jaw, is as 5 to 8, the head being, therefore, rather more than half the length of the neck; its proportion to the whole skeleton is about 1 to 6. This large proportionate size of the head corresponds very nearly with that of *P. megacephalus*, Stutchbury, and an undescribed species from Redcar, in the Museum of the Yorkshire Philosophical Society, named *P. Zetlandicus* by Professor Phillips, from both of which it differs in several very important particulars.

Note.—Since reading the above paper, the authors have received information, through the kindness of Mr. Martin Simpson, the Curator, respecting a *Plesiosaurus* in the Whitby Museum, which in its proportional measurements appears to approximate very closely with the above species.

On an Extinct Volcano in Upper Burmah. *By* W. T. Blanford, *F.G.S.*

The most conspicuous object visible from the River Irawaddi, between its mouth and the capital of the kingdom of Ava, is the lofty hill of Puppa, which lies about 100 miles beyond the British frontiers, on the east or left bank of the river, and about 35 miles E.S.E. of the town of Pagau, famous for the enormous number and the magnificent architecture of its ancient Buddhist temples. The whole undulating plain between the River Irawaddi and Puppa Hill consists of the Upper Tertiary sands. The hill itself is a fine extinct volcano, its height probably a little under 5000 feet. The upper part of the cone is free from the forest which covers the lower portion, and a complete change in the flora and the presence of some plants common to temperate climates show the effect of the altitude reached. The upper part of the cone is solely composed of ash-beds; towards the base there is an abundance of old lava-flows, and a thin cap of these has protected a portion of the soft underlying sands, so that the hill is surrounded by a broad terrace, the edges of which rise abruptly 300 or 400 feet from the country around. Some small, flat-capped hills, detached from the mass, present a peculiar appearance, from their cap of black ash-beds and lava contrasting with the white sand of which they are principally composed.

The following section was obtained from an examination of the cliff surrounding the terrace (all the beds horizontal):—

1. Lava-flow, forming a cap of variable thickness.
2. Soft white sand, somewhat micaceous, about 80 feet.
3. (Very local) bed of pumice, 5 feet.
4. Volcanic ash and scoriæ, with rounded quartz-pebbles, varying in thickness from 5 to 20 feet.
5. Ferruginous conglomerate, containing the iron-ore of the country, thin.
6. Soft, coarse, yellowish sand, containing pebbles, about 100 feet seen.

The author believed that the sands above and below the ash-bed No. 4 were identical with those containing fossil wood and bones in various parts of the Irawaddi valley. He concluded that the commencement at least of the volcanic outburst of Puppa was synchronous with the existence of *Mastodon latidens* and the several Pachydermata and Ruminantia, remains of which have been collected at Genanthamug and other places in Upper Burmah. These beds contain several fossils identical with those of the Sewalik beds of India, which have commonly been considered as Miocene. The large proportion of bones of Ruminants (Oxen and Deer) in the Irawaddi beds may perhaps suggest a somewhat more recent epoch.

The shape of the volcanic cone is well preserved, with the exception of the crater being broken down on one side, so that no lake exists within. The climate, however, of this portion of Burmah is extremely dry, and the action of subaërial denudation is probably very slow, so that the mountain may have preserved its form for a very considerable geological period. The existence of a peculiar flora on the upper portion (*Pteris aquilina*), and of a land-shell (*Helix Huttoni*) common to the slopes of the Himalayas and the Nilgherris, but not yet found in any portion of the plains of India or Burmah, seems to show that the cone has not only been in a quiescent state, but also covered with vegetation, at a time when the condition of the surrounding country was very different from what it is at present, since it is scarcely possible that ferns or land-shells should cross the large area of dry and arid land intervening between this isolated peak and the nearest hills (60 or 80 miles at least).

The position of this extinct cone is interesting, from the circumstance of the well-known great volcanic line of the Eastern Islands terminating at Banca Island (perhaps at Chedalia), in the Bay of Bengal. Whether in Tertiary times this volcanic line extended to the N. towards China is a question for future explorers of the as yet unknown regions of Upper Burmah, Yunan, and Thibet.

On some Flint Implements from Amiens. By the Rev. T. G. Bonney, *F.G.S.*

Notes on Deep or Artesian Wells at Norwich.

By the Rev. J. Crompton, *M.A.*

The object of the paper is to put on record the facts connected with an attempt, by Messrs. J. J. Colman, of London and Norwich, to bore through the Chalk to the Lower Greensand, for the purpose of obtaining water free from the impurities of that within the range of the Chalk of the neighbourhood.

The operation is performed by Messrs. Mather and Platt's machine. In the hard chalk the rate of penetration has been 20 to 25 feet per day for 500 feet.

After a few feet of alluvium, the borer passed through hard chalk with flints, at distances of about 6 or 7 feet apart, for 700 feet, with the exception of 10 feet at the depth of 500 feet, where the rock was soft and of a rusty colour; thence the flints were thicker, viz. about 4 feet apart, to the depth of 1050 feet; then 102 feet were pierced of chalk, free from flints, to the upper greensand, a stratum of about 6 feet, and next Gault for 36 feet, the whole boring being full of water to within 16 feet of the surface.

In this Gault the proceeding has been unfortunately arrested by breakages of the rope, leaving the boring-heads lying across the passage, baffling all attempts to remove them.

The strata passed through are—

	feet.
Alluvium	12
Hard chalk with flints	483
Soft chalk	10
Hard chalk	190
Hard chalk, flints closer	350
Chalk without flints	102
Upper greensand	6
Gault, not yet passed through	36
	1189

The fossils brought up have been the ordinary species found in the Chalk, as *Spatangus cordiformis*, and Sharks' teeth (one, that of *Lamna Mantellii*). From the Gault, *Ammonites lautus*, *symmetricus*, and fragments of *Inoceramus*.

The Foraminifera in the Gault are—

Orbulina, common.
Lagena, rare.
Nodosaria, not uncommon.
Frondicularia, rare.
Dentalina, not uncommon.
Entosalenia, rare.
Rotalina, not uncommon.
Polymorphina, not uncommon.
Textularia, common.
Globigerina, common.
Fragments of Bryozoa, occasionally.

In the Chalk, at 500 feet depth, the Foraminifera are more sparsely distributed; they consist chiefly of the two genera *Globigerina* and *Textularia*. *Rotalina* more rare. The same is the case at 110, 400, and 1000 feet in depth.

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On Flint Implements from Abbeville and Amiens. By Dr. DAUBENY, *F.R.S.*

Dr. Daubeny exhibited some flint implements obtained from the post-pliocene deposits near Abbeville and Amiens, with a view of eliciting the opinion of the Section with respect to their antiquity, and the possibility of their being formed by other than human agency.

On the last Eruption of Vesuvius. By Dr. DAUBENY, *F.R.S.*

The author confined himself to those phenomena which appeared to present some novelty, and to have a bearing upon the general theory of volcanic action. Vesuvius appears during the last few years to be entering a new phase of action. Its eruptions are more frequent, but less violent, than they were formerly; they proceed from a lower level than they did at an earlier period; and they give vent to certain volatile and gaseous principles, such as the vapour of naphtha and light carburetted hydrogen, or marsh-gas, never before detected. The last eruption has likewise caused an elevation of the coast to the height of 3 feet 7 inches above the level of the sea, which has not been observed to take place on any former occasion. In speculating on the causes which have produced these changes in the nature of the operations of Vesuvius, the author first considered the theory which recognizes a second class of volcanos distinct from those ordinarily known as such, and designated by the name of mud-volcanos. As these latter are characterized by the emission of carburetted hydrogen and naphtha, as well as of semifluid mud, it might be suggested by those who regard them as partaking of the nature of volcanos, that Vesuvius from emitting these same products was now passing into the condition of a mud-volcano. But the author finds reason for denying that the so-called mud-volcanos, of which Macalube in Sicily and Taman in the Sea of Azof are types, have anything in common with genuine ones, such as Vesuvius; and he therefore contends that the above products are generated simply by the action of volcanic heat upon contiguous beds of Apennine limestone containing bituminous matters imbedded. Hence would arise the enormous evolution of carbonic acid observed, and the carburetted hydrogen as well as vapour of naphtha which accompany it, and which may be regarded as the secondary and incidental products of volcanic action, whilst the muriatic and sulphurous acids are the primary and essential ones. The author concluded by recommending to the explorers of volcanic phenomena an accurate examination of the gases evolved, as the best clue to an explanation of the true nature and cause of volcanic action. The latest researches of Deville and others on volcanic emanations present nothing irreconcileable with that chemical theory which the author has so long espoused; but all he asks of geologists is diligently to record the facts, chemical as well as physical, which volcanos present, instead of contenting themselves with simply referring the eruptions to certain great cosmical changes which they imagine to have taken place.

On the Wokey Hole Hyæna-den. By W. BOYD DAWKINS, *F.G.S.*

The author described the peculiar features of the den—its accidental discovery, it being filled up to the roof with débris, stones, and organic remains—and showed the evidence of human occupation. In three areas in the cave he found ashes of bone—either of *Rhinoceros* or *Elephas*—associated with flint and chert implements of the same type as those of Amiens and Abbeville, and as those of Suffolk. They were, however, of ruder workmanship, and possibly are of an earlier date. They were found underlying lines of peroxide of manganese and of comminuted bone, and overlying, in one of the three areas, remains of the Hyæna, which mark the old floors of the cave. From this he inferred that "Man, in one of the earlier, if not the earliest, stages of his being, dwelt in this cave, as some of the most degraded of our race do at present; that he manufactured his implements and his weapons out of flint, brought from the chalk downs of Wilts, and the least fragile chert of the greensand of the Blackdown Hills, and arrow-heads out of the more easily fashioned bone. Fire-using, indeed, and acquainted with the use of the bow, he was far worse armed, with his puny weapons of flint and bone, than his contemporaries with their sharp claws and strong teeth. The very fact that he held his ground against them shows that cunning and craft more than compensated for the deficiency of his armament. Secondly, that as he was preceded in his occupation, so was he succeeded by the Hyæna." He then gave a brief summary of the organic remains found, comprising upwards of 1000 bones, 1016 teeth, and 15 jaws, belonging to

Hyæna spelæa.
Felis spelæa.
Felis.
Ursus spelæus.
Ursus arctos.
Ursus.
Lupus.
Vulpes.
Elephas primigenius.
Equus.
Rhinoceros tichorhinus.
Rhinoceros hemitæchus (Falc.).
Bos primigenius.
Bos.
Megaceros hibernicus.
Cervus.
Cervus tarandus (=C. Guettardi and C. Bucklandi, Owen, Foss. Mamm.).
Cervus Elaphus (=Strongyloceros spelæus, Owen, Foss. Mamm.).

Rhinoceros hemitæchus may perhaps refer the date of the cave back to the earlier part of the newer Pliocene. At all events this is the second instance known of this associate of *Elephas antiquus* being found together with traces of man.

On Specimens of Flint Instruments from North Devon. *By the* Rev. J. Dingle.

On Flint Instruments from Hoxne. *By* Mr. Doughty.

On the Geology of Burren, Co. Clare. *By* F. J. Foot, *M.A., G.S.I.*

This district is composed of the beds of the upper portion of the Carboniferous Limestone, capped on the S.W. by the basal shales of the Coal-measures. Contrary to what is usually the case, the limestone rises into hills upwards of 1000 feet above the sea, and the sides of these are a step-like succession of steep cliffs or bluffs, with broad, flat terraces of bare rock at their feet; these lines of cliff are accurately laid down on the map, and are often traceable for many miles. Excepting in the valleys, where there are accumulations of drift (a mixture of limestone-gravel and the débris of granite), the district is almost entirely uncovered by soil, and the singular form of the hills, together with their barrenness, imparts a most peculiar aspect to this part of Ireland. The strata are nearly horizontal, but have a general dip to the S. of about 1° 30′. This dip prevents the lines on the map being actual contours. The limestone varies in colour from pale to dark grey, and in texture is either compact or crystalline. It contains locally, Corals, Productæ, Crinoids, Nautili, Spiriferæ, &c. In many places it is highly magnesian, and there are some good Dolomites, as well as bands of Chert. It is traversed by several sets of joints, which cut up the rock into numerous prisms of various sizes and forms; and the extensive flat surfaces have somewhat the appearance of that of a glacier; an accurate plan of a portion of one of these surfaces was also exhibited. This remarkable tract of country has altogether an area of about 250 square miles.

On some Models of Foraminifera. *By* Dr. Fritsch.

On the Skiddaw Slate Series. *By* Professor Harkness, *F.R.S., F.G.S.*

The Skiddaw slates of Professor Sedgwick form the lowest of the sedimentary rocks of the North of England. They are overlaid by a thick series of greenish-grey rocks, which, for the most part, consist of porphyries and ashes; these latter have been succeeded by the Coniston limestone of Professor Sedgwick, the equivalent of the Bala limestone.

The sequence of the Skiddaw slates is well shown in the hills which lie west of Bassenthwaite and Derwentwater Lakes. In this portion of Cumberland, these slaty strata, with their associated flaggy beds, are seen at Newlands, passing under the superior greenish-grey rocks. A section from this place northwards to Sunderland, where the Carboniferous deposits of West Cumberland make their appearance, shows two well-marked anticlinals; and in several localities in this section fossils occur. These consist of *Graptolites* and a branching *Bryozoon*; of the former, the genera appertain to *Graptolites, Diplograpsus, Didymograpsus, Dichograpsus,* and *Tetragrapsus.* A new form of phyllopod Crustacean is also found in several localities in the course of this section. The fossils of the Skiddaw slates are met with only in the flaggy beds; but whenever rocks of this nature occur, they afford fossils.

A section from Matterdale, on the N. side of Ullswater, across the Skiddaw slates to the Carboniferous strata lying N. of Caldbeck-fells, also affords fossils. That section does not, however, exhibit the same arrangement of the strata. The inclinations in this part of the Skiddaw slate of Cumberland are for the most part S.S.E., and no well-developed axis occurs in this section. This portion of the Skiddaw-slate area is intersected in the valley of the Caldew by granite—the Skiddaw Forest granite of Professor Sedgwick. The results of the author's observations on this granite of the valley of the Caldew induce him to infer that it is an extension W.S.W. of the syenite forming the northern half on Carrock-fell.

Three small areas of Skiddaw slate are found on the eastern margin of the Lake district. One of these is on the S.E. side of Ullswater, and is intersected by a stream called Eggbeck. The other occurs near Rossgill; and the third at Thornshipgill, a short distance west of Shap. In the two latter slate-pencil quarries were formerly worked. In these three areas the author has also met with fossils similar to some of those which have been obtained in the area west of Derwentwater and Bassenthwaite Lakes.

Another area occupied by Skiddaw slate is Blackcomb, in the S.W. of Cumberland. In this hill the inclinations are N.N.W.; and along the Whicham valley, on the south flank of Blackcomb, a great fault, previously alluded to by Professor Sedgwick, occurs. The Skiddaw slates of Blackcomb also yield fossils.

With reference to the position of the Skiddaw slates, the author is induced to infer that they appertain to the Lower Llandeilo; and this conclusion is still further corroborated by Mr. Salter, who, from an examination of the fossils, is led to infer the Lower Llandeilo age of the Skiddaw slate series.

Notice of an Ancient Sea-bed and Beach near Fort William, Inverness-shire.

By J. Gwyn Jeffreys, *F.R.S., F.G.S.*

After making some remarks on the subject of raised beaches and their number in this country, as well as with respect to the Arctic nature of the shells which had been found in the Clyde beds, as well as in Yorkshire, Staffordshire, Norfolk, and other counties, Mr. Jeffreys described some deposits to which his attention had been drawn by Captain Bedford, R.N., and which consisted of an ancient sea-bed and beach lying in juxtaposition to each other. The bed is lowermost, and contains species which usually inhabit a moderate depth of water: the beach appears to have been formed after the bed was upheaved, because it contains littoral species and shells which must have been thrown up by the tide. The organic remains found in the bed and beach represent fifty-nine species, including forty-eight of Mollusca, The analogy between these deposits on the one hand, and the Coralline and Red Crag on the other, was pointed out; but their palæontological contents being of a different kind, the Inverness-shire and Crag deposits were in all probability not contemporaneous. The now-described deposits underlie several other strata, which may belong to the Boulder-clay formation; but this last is a doubtful point. Nearly all the species of Mollusca met with on the present occasion live in the adjacent seas; but a few of them (e. g. *Pecten Islandicus, Columbella Holböllii, Littorina squalida, Mangelia pyramidalis, Margarita costulata, Natica clausa,* and *Trophon Gunneri*) now exist only in more northern latitudes. Mr. Jeffreys, however, regards this assemblage of shells as Scandinavian, and not as Arctic. A Table of species was appended to the paper, showing the proportion which inhabits the Arctic, Scandinavian, and Scotch seas, as well as of those which occur in a fossil state in the Crag, Clyde beds, and Kelsey Hill (or Yorkshire) deposits.

MOLLUSCA.

[As in the Kelsey Hill list, these are alphabetically arranged for facility of reference; and the British species bear the names proposed by Forbes and Hanley. The species marked with an asterisk have not been found living in the British seas.]

Scale of frequency :—a. = abundant.—c. = common.—r.c. = rather common.—r. = rare.—v.r. = very rare.

No.	Name of Species.	Synonyms.	Scale of frequency.	Arctic.	Scandinavian.	Scotch.	Range of depth.	Red Crag.	Clyde beds.	Kelsey Hill.	Remarks.
	Bivalves.										
1	Anomia ephippium, var. squamula	....	c.	....	—	—	littoral to 160 fathoms.	....	—	—	A coralline crag species, according to Searles Wood.
2	—— striata	A. undulata, *Gmelin*	v. r.	....	—	—	15–50	—	—	....	A variety of *A. Patelliformis.*
3	Astarte compressa, var. ..	A. striata, *Leach.* Crassina multicostata, *Smith.*	r. c.	—	—	—	1.–140	—	—	—	
4	—— elliptica	....	c.	—	—	—	4–140	—?	—	....	
5	—— triangularis	....	v. r.	....	....	—	10–60	—	....	....	A single valve only.
6	Leda pygmæa	Nucula gibbosa, *Smith*	r.	—	—	—	40–130	....	—	....	Coralline crag (S. Wood).
7	Modiola modiolus	....	a.	....	—	—	3. 30	—	—	....	
8	Mya truncata	....	v. r.	—	—	—	1.–70	—	—	—	A single valve only.
9	Mytilus edulis	....	v. r.	—	—	—	1.–140	—	—	—	Pearls only.
10	Nucula nucleus?	....	v. r.	....	—	—	8–80	—	—	—	A single valve, found by Mr. Jamieson, and which he supposed was this species; but the specimen was broken in extracting it from the shell layer, and it was not preserved.
11	Pecten Danicus	P. Jamesoni, *Smith.*	v. r.	....	—	—	20–85	—	—	....	A fragment only.
•12	—— Islandicus, *Müller*, var.	P. Fabricii, *Philippi*	c.	—	—	....	8–140	....	—	....	Perhaps a distinct species.
13	—— maximus	....	v. r.	....	—	—	10–30	—	—	....	A fragment only.
14	Turtonia minuta	....	v. r.	—	—	—	1.–25	....	....	....	A fragment only.
	Univalves.			7	13	13		10	12	5	
15	Acmæa virginea	....	c.	....	—	—	1.–60	—	—	....	Of a large size.
16	Aporrhais pes pelecani	....	v. r.	....	—	—	8–82	—	—	....	A fragment only.
17	Buccinum undatum	....	r. c.	....	—	—	1.–70	—	—	—	
18	Chiton albus	....	[illegible]	—	—	—	5–85	....	[illegible]	[illegible]	A plate only.

21	—— ruber		r.	—	—	—	[illegible]	....	....	....	[illegible]
*22	Columbella Holböllii, *Beck*		r. c.	—	—	....	....	....	....	....	Occurs living as far south as Bergen, according to Sars. Dredged on the north-east coast of Ireland, as well as in the Moray Firth, but probably pleistocene.
23	Lacuna pallidula		v. r.	—	—	—	1.–12	....	....	....	
24	—— puteolus		v. r.	....	—	—	1.	....	....	....	Finmark, according to Sars.
25	—— vincta & var. elongata		a.	—	—	—	1.–30	....	—	—	The variety merges into the typical form by insensible gradations.
26	Littorina litorea		v. r.	....	—	—	1.–5	—	—	—	
27	—— rudis and var.		r. c.	—	—	—	1.	....	—	—	The variety is *L. saxatilis* of Johnston, and inhabits high rocks above ordinary high-water mark.
*28	—— squalida, *Brod. & Sow.*	Turbo expansus, *Smith*	c.	—	—	....	....	....	—	—	The most southern locality where it occurs in a living state is Bohuslan, in Sweden.
*29	Mangelia pyramidalis, *Ström*		v. r.	—	—	....	50	....	....	—	A specimen, two-thirds grown, found by Mr. Jamieson.
30	—— turricula		v. r.	—	—	—	5–140	....	—	—	
*31	Natica clausa, *J. Sowerby*	N. affinis, (*Gmelin*) *Mörch*	r. c.	—	—	....	1.–150	—	—	—	
32	—— Helicoides	N. Islandica, (*Gmel.*) *Mörch*	v. r.	—	—	—	3–82	—	—	—	
33	Patella vulgata		v. r.	....	—	—	1.	—	—	....	An imperfect specimen only.
34	Puncturella Noachina	Patella Fissurella, *Müller*	r. c.	—	—	—	4–120	....	—	....	Bridlington beds (S. Wood). Kelsey Hill (Darbishire).
35	Purpura lapillus		r.	....	—	—	1.–20	—	—	—	
36	Rissoa parva, var.	Turbo interruptus, *Montagu*	v. r.	....	—	—	1.–40	....	....	....	
37	—— striata		c.	—	—	—	1.–25	....	—	....	Coralline crag (S. Wood).
*38	Skenea costulata, *Möller*	Cyclostrema costulata, *Mörch*	r. c.	—	....	....	....	....	....	....	
39	—— divisa		v. r.	....	—	—	1.–12	....	....	....	One specimen only.
40	—— nitidissima	Omalogyra nitidissima, *Jeffr.*	v. r.	....	—	—	1.–10	....	....	....	
41	—— planorbis		r. c.	—	—	—	1.–40	....	....	....	
42	Trochus cinerarius	T. perforatus, *Smith*	r. c.	....	—	—	1.–30	—	—	....	Kelsey Hill (Darbishire).
43	—— Helicinus		r. c.	—	—	—	1.–30	....	....	....	
44	—— millegranus	T. Martini, *Smith*	v. r.	....	—	—	5–50	....	—	....	Coralline crag (S. Wood).
45	—— tumidus		r. c.	....	—	—	1.–35	—	—	....	
46	—— undulatus	T. inflatus, *Smith*	r. c.	—	—	—	1.–100	....	—	....	
47	Trophon clathratus		a.	—	—	—	16–120	....	—	—	
*48	—— Gunneri, *Lovén*	Fusus Peruvianus, *Smith*	r.	—	—	....	8–150	....	—	—	Perhaps a variety of *T. scalariformis*, Gould.
				26	46	41		20	32	17	

No.	Name of Species.	Synonyms.	Scale of frequency.	Arctic.	Scandinavian.	Scotch.	Range of depth.	Red Crag.	Clyde beds.	Kelsey Hill.	Remarks.
	CIRRIPEDIA.										
49	Balanus crenatus, *Bruguière*		v. r.	....	—	—	1.–25	....	....	—	
50	—— porcatus, *Da Costa*		r.	....	—	—	1.–100	....	—	....	
51	Verruca Strömia, *Müller*		r.	....	—	—	1.–100	....	—	....	
				26	49	44		20	34	18	
	ANNELIDA.										
52	Serpula vermicularis, *Linné*		r.	....	—	—	....	....	—	....	
	ECHINODERMATA.										
53	Echinus Droebacensis, *Müller*	E. neglectus, *Forbes*	r. c.	....	—	—	15–60	....	....	....	Portions of plates and spines.
54	—— Norvegicus, *Sars*		v. r.	....	—	—	75–82	....	....	....	Spine only.
	POLYZOA.										
55	Lepralia ventricosa, *Hassall*		r.	....	—	—	40–75	....	....	....	A coralline crag species, according to Busk.
	FORAMINIFERA.										
56	Miliolina seminulum, var. oblonga, *Linné*		r. c.	....	—	—	20–85	....	....	....	
57	—— trigonula, *Lamarck*		v. r.	....	—	—	25–50	....	....	....	
58	Truncatulina lobatula, *Walk.*		r. c.	....	—	—	10–100	....	....	....	
	SPONGES.										
59	Cliona celata, *Johnston*		r.	....	—	—	10–80	....	....	....	
				26	57	52		20	35	18	

On the Geology of the Gold-fields of Otago, New Zealand. By W. LAUDER LINDSAY, *M.D. & F.R.S. Edinburgh, F.L.S. & F.R.G.S. London, &c.*

The author had made a personal geological survey of the Tuapeka and other gold-fields of Otago between October 1861 and January 1862, some of the general results whereof were published, under the section on the "*Geology of Otago,*" in a Lecture by him, printed in Dunedin in January 1862, entitled "*The Place and Power of Natural History in Colonization, with special reference to Otago; being portions of a Lecture prepared for, and at the request of, the Young Men's Christian Association of Dunedin,*" and issued as a pamphlet by and under the auspices of the said Association.

He had also formed and brought home a considerable collection of the rocks and minerals of the Otago gold-fields, with relative field-memoranda, maps, and drawings.

The general results of his observations and deductions may be tabulated as follows:—

1. The gold and gold-bearing rocks of Otago do not differ essentially, *quoad* mineralogical or geological characters, from those of every other part of the world hitherto known to be auriferous.

2. The original matrix of the gold is quartz; and the latter occurs interbedded in, or associated with, metamorphic slates, especially of the gneiss, mica, talc, chlorite- and clay-slate families.

3. These slates vary greatly in mineralogical character; but they bear a closer resemblance to those of central and southern Scotland (Grampians, &c.) than to the more altered Silurian auriferous slates of Victoria (Australia).

4. The slates in question are probably of Silurian age; but this has yet to be proved, for they are themselves non-fossiliferous; and as yet the subjacent rocks are unknown.

5. At various points there are evidences of considerable disturbance in the schistose strata by the intrusions and eruptions of trappean rocks, apparently referable to the Tertiary era.

6. The valleys among the schistose hill-ranges are generally occupied by alluvial drifts, apparently of Tertiary age, naturally divisible perhaps into a lower or older group, characterized by its abundant lignites, and a superficial or newer series, which is chiefly the seat of the operations of the gold-miner.

7. The lignitiferous or older drift consists chiefly of quartz gravels—in certain deposits cemented by means of peroxide of iron and other materials into a hard red conglomerate—associated with thinner strata of clays, sands, and gravels. This series of beds sometimes occurs at a height of from 500 to 1000 feet above the sea-level, on the flanks of trappean and other hills.

8. The upper or newer drift bottoms—the valleys and "flats," so common in the hilly parts of the country (where the hills are schistose)—consist essentially of (*a*) clays, blue, yellow, or red; (*b*) boulder-clays; and (*c*) gravels, so called, which are really the little-worn or abraded débris of the subjacent and circumjacent slates, and which are more correctly denominated by the miner's phrase, "chopped slate."

These beds are immediately superjacent (in the order in which they are above enumerated) on the generally upturned and very irregular edges of the slates; and the latter, according to their mineralogical character, give a dominant colour to the former,—the clays and gravels of the gneiss being bluish or greyish, of the chlorite-slates greenish, of the mica-slates, in proportion as they are less or more ferruginous, yellow or red.

9. Gold occurs chiefly in the gravel or "chopped slate" above described,—this constituting the "wash-dirt" of the miner. It is frequently found most abundantly in "pockets" (hollows or crevices) of the irregular upturned edges of the subjacent slates, whereon the gravel immediately reposes. It is disseminated through the clays in some localities; while in others it is sometimes collected in quantity in cavities, or "pockets," under the boulders of the boulder-clay beds.

10. The gold is partly granular or gunpowder-like, partly scaly, nuggety, or crystallized; and it exhibits every gradation, intermixture, and variety of each of these forms or kinds in different localities.

11. It is associated, in different localities, with iserine (titaniferous iron-sand);

iron-pyrites, common and arsenical (mispickel); cassiterite (tin-sand or oxide of tin); topaz (of the *gouttes-d'eau* character, blue or colourless); garnets, and other minerals.

Much of Otago remains yet to be explored, especially the mountainous western portion of the province; but, from the geological structure of those portions of the province he personally examined, the author draws or makes the following inferences, deductions, or predictions:—

1. That the geological basis of the greater part of Otago consists of auriferous metamorphic slates. This refers especially to the great central and western mountain-ranges; for instance, those which encircle the large interior lakes (Hawea, Wanaka, and Wakatip).

2. That these great mountain-systems are probably the source of the tertiary drift so abundantly distributed over the lower parts of the province, which drift consists mainly of quartzose and schistose débris.

3. That this tertiary drift, in both its lignitiferous and more strictly auriferous series of beds, will be found much more extensively and largely distributed over the province than at present.

4. That gold is very extensively and largely distributed over the province; and that many gold-fields remain to be discovered, especially in the interior; though nothing short of actual mining, or "digging," can determine the localities of "*payable* gold-fields."

5. That the supply of gold is at present practically *unlimited*; and that the auriferous resources of Otago are only beginning to be developed, and will only be fully developed in the course of many years, by—*a*. The addition of quartz-mining, and others of the skilled branches of gold-mining, to the shallow or "alluvial digging," to which the miner's operations are at present mainly confined. This implies a greater concentration of attention than at present on the auriferous *quartzites*, from which the drift or alluvial gold has originally been derived, the working whereof, should they exist to any extent, is much more likely to yield a permanently remunerative employment, and a permanent and valuable source of revenue, than the said "alluvial digging." *b*. The systematic application of improved chemical and mechanical, or chemico-mechanical, processes to gold-mining, and the expenditure thereon, or application thereto, of suitable capital. *c*. The establishment of gold-mining as one of the permanent industrial resources of the province. *d*. The systematic prospecting, by exploring and experimental parties suitably equipped, partly geological and surveying, partly mining and "digging." *e*. The liberal and enlightened encouragement of mining and of the miners by the construction of rail- and tramways, the opening-up of roads, the building of bridges, the establishment of townships, the sale of waste lands at suitable prices, the adequate supply of fuel by the working of lignite-beds or otherwise, the institution of proper mining laws and mining boards, and other measures pertaining strictly to the legislative function of the State.

The following Tables illustrate the comparative prolificness of the Otago gold-fields, from their discovery in June 1861 to the end of March 1862:—

I. Showing the amount of gold brought to Dunedin by each Government escort from the chief gold-fields of Otago (compiled from the Receiving Officer's returns).

Date of arrival of escort.	Tuapeka.	Waitahuna.	Waipori.	Total by each escort.
1861.	ozs.	ozs.	ozs.	ozs.
July 12	480	......	......	480
„ 31	1,462	......	......	1,462
August 21	5,056	......	......	5,056
September 4	7,759	......	......	7,759
„ 15	11,280	......	......	11,280
October 4	12,126	......	......	12,126

TABLE I. (*continued*).

October 18	14,438	......	......	14,438
„ 31	19,119	......	......	19,119
November 15	30,584	4,650	......	35,234
„ 21	15,402	5,688	......	21,090
„ 28	13,520	4,061	......	17,581
December 5	10,198	4,338	......	14,536
„ 12	10,953	5,178	......	16,131
„ 19	9,594	4,614	......	14,208
„ 26	10,080	3,935	......	14,015
1862.				
January 2	8,447	3,216	......	11,663
„ 9	7,435	3,349	......	10,784
„ 16	8,867	2,612	......	11,479
„ 25	9,488	1,667	......	11,155
„ 30	8,722	1,588	969	11,279
February 6	9,749	2,032	......	11,781
„ 13	8,027	2,131	......	10,158
„ 20	7,856	1,921	......	9,777
„ 27	7,308	1,833	1617	10,758
March 1	5,901	1,144	195	7,240
„ 13	7,201	1,695	604	9,500
„ 20	6,054	1,270	......	7,324
„ 27	5,447	1,399	1293	8,139
Total	272,553	58,321	4678	335,552
Average by each escort	9,734	2,916	936	11,984

II. Showing the quantity and value of, and duty on, gold exported from Otago between 3rd August, 1861, and 31st March, 1862.

	Quantity.		Value.			Duty.		
1861.	ozs.	dwts.	£	s.	d.	£	s.	d.
Aug. 3 to Dec. 31	187,695	9	727,319	17	5	23,461	19	10
1862. Jan. 1 to March 31	170,770	13	661,736	5	4	21,346	8	6
Total	358,466	2	1,389,056	2	9	44,808	8	4

III. Showing the quantity and value of all the gold exported from the whole of New Zealand up to 31st March, 1862.

Port of export.	Produce of gold-fields in province of	Quantity.	Value.
		ozs.	£ s. d.
Dunedin.. Lyttleton.. Nelson ... Wellington	Otago	359,639	1,393,600 0 0
Nelson .. Wellington	Nelson	46,591	180,541 0 0
Auckland	Auckland	354	1,372 0 0
Total	....	406,584	1,575,513 0 0

Tables I. and II. are compiled from statistics given in the 'Otago Daily Times' of April 6, 1862, and Table III. from those given in the 'Otago Colonist' of July 15, 1862.

On the Geology of the Gold-fields of Auckland, New Zealand. By W. LAUDER LINDSAY, *M.D. & F.R.S. Edinburgh, F.L.S. & F.R.G.S. London, &c.*

The author had personally made a geological examination of the Coromandel gold-field, in the province of Auckland, in February 1862, having previously spent several months on a similar survey of the Otago gold-fields. He described Coromandel as a different type of gold-field from Tuapeka (Otago), and, as such, of interest as illustrative of the general geology of the New Zealand gold-fields. The main results of his observations and deductions may be concisely stated thus:—

1. The geology of the northern gold-fields of New Zealand, including those of Nelson as well as of Auckland, does not differ essentially from that of the southern or Otago gold-fields (as the geology of the latter is described in his paper "On the Geology of the Otago Gold-fields," save in so far as regards certain minor details. The parent slates, for instance, are in the north more frequently of a clay-slate or argillaceous character than in the south; the auriferous quartzites are frequently developed to an extent as yet unknown in Otago; the evidences of trappean disturbance are more numerous, and the metamorphism of the slates by the contiguity of the erupted or intruded traps better marked. Nor does the character of the gold differ materially, save in so far as, in certain localities, it is more generally associated with its quartz matrix.

2. The Coromandel Peninsula consists mainly of a mountain ridge, running nearly north and south; the mountains having a bold serrated outline, and varying in height from 1000 to 2000 feet. The valleys between the spurs given off laterally by this main or dividing range are of the character generally of ravines or gorges, occupied by mere mountain streams; the "flats" or alluvial tracts at their mouths, and on the coast, are inconsiderable.

3. This mountain-range consists apparently of slates of Silurian age, generally of argillaceous character, but greatly altered by contact with, or proximity to, numerous outbursts or intrusions of trappean and other rocks. The mountains are so densely wooded, and so difficult of access, that it is only here and there in the gorges of the streams that sections of these slates may be examined. In these sections the slates are frequently found to resemble Lydian stone or the slaty varieties of basalt (such as clinkstone); while they are disposed more or less vertically, their irregular upturned edges affording the most convenient and abundant "pockets" for the detention and storage of the alluvial gold washed from the higher grounds.

4. [Local geologists describe the fundamental rock of the Coromandel mountain-system as granitic, and the granite as forming here and there the "aiguilles" of the dividing ridge. The author met with no granite *in situ*; nor did he discover granitic boulders or pebbles in the boulder-clays of the auriferous drift, or in the shingly beds of the mountain streams about Coromandel Harbour.]

5. The Coromandel slates are characterized by their prominent and numerous quartz "reefs," consisting of auriferous quartzites. Here and there, where the dense vegetation admits, these reefs are met with *in situ*, frequently as "dykes," standing prominently above the general level of the slates; sometimes forming the top of the dividing ridge itself. The proximity and abundance of such quartzites are sufficiently indicated by the immense numbers of huge quartz-boulders or blocks which bestrew the low ground and occupy the ravines and gorges, which blocks are characterized by comparative angularity. The quartz is frequently of the porous, light, spongy character so prevalent in the gold-fields of Australia, Nova Scotia, California, and other auriferous countries; and its colour is frequently buff, brown, ochrey, or vermilion, the result, apparently, of different degrees of ferruginous impregnation.

6. The auriferous drift is mostly of the character of the newer or upper Tertiary drifts of the Otago gold-fields, consisting essentially of—*a.* variously coloured clays; *b.* boulder-clays, also variously coloured; and *c.* gravels, of the "chopped slate"

character, the débris of the component rocks of the parent ranges, which gravels rest immediately on the "bed-rock" or slate. In this gravel, as at Otago, the gold chiefly occurs; hence to these gravels are, as yet, mainly directed the operations of the miner.

7. The gold itself occurs in the form of dust, scales, or nuggets—frequently as scaly nuggets or "pepites," but still more generally dendritically disseminated in quartz-pebbles, which are usually ochrey or brownish in colour.

8. It is largely associated with iserine (titaniferous iron-sand), apparently of the character of that so abundant at Taranaki. This mineral, indeed, appears to be associated with gold in almost all the New Zealand gold-fields.

9. The prevalent volcanic rocks, which burst through, overlie, or are otherwise associated with the slates, are mainly various trachytes, tuffs, basalts, and syenites. A hard breccia, consisting to a great extent of fragments of jasper and flint, resembling somewhat the "cement" or quartz conglomerate of the older or lower Tertiary auriferous drifts of the Otago gold-fields, occurs on Beeson's Island, in Coromandel Harbour, which island is mainly or altogether tufaceous. Boulders of basalt and syenite bestrew the tops of the hills which form the greater part of the said island; and basaltic boulders are associated with quartzose ones in the shingly beds of the mountain-streams of Coromandel and in the boulder-clays of the auriferous drift.

Contrasting the Tuapeka (Otago) with the Coromandel gold-fields, the author indicated the following respective peculiarities:—

At Tuapeka (Otago):—*a*. The bare open country, resembling the Lammermoors of Scotland, consisting of gently undulating "ranges," of a height generally of from 500 to 1500 feet. *b*. The abundance of the auriferous drift, and the comparative insignificance or scarcity of the parent quartzites. *c*. The scarcity of timber for fuel and slabbing; but, on the other hand, the presence of lignites. *d*. The inclement climate. *e*. The difficulties of land-communication with the capital (Dunedin), arising from insufficient roads. *f*. Unlimited powers of "prospecting" and "working," arising from the absence of a native population.

At Coromandel:—*a*. The precipitous mountain-ranges, densely covered with a jungly vegetation to the top; the hill-bases impinging directly on the sea-margin, without the intervention of "flats," save to an insignificant extent. *b*. The scarcity of the auriferous drifts, and the abundance of the parent quartzites. *c*. The abundance of timber for fuel, mining-works, and dwellings. *d*. The superior climate, arising from its geographical position, 800 miles more northerly. *e*. The facilities of water-communication with the capital (Auckland), 45 or 50 miles distant. *f*. Difficulties and dangers of prospecting and working, arising from the presence of a jealous, hostile proprietary native population.

From his observations at Coromandel and Tuapeka, as well as in the other parts of New Zealand he visited during his tour of 1861-62, the author makes the following statements, inferences, or predictions:—

1. That while there is, at Coromandel, a very limited and insignificant field for *alluvial digging*, there is ample scope for *quartz-mining*.

2. That the auriferous resources of Coromandel will only be fully developed in the course of many years by the application of all modern improvements in chemistry and mechanics to *systematic mining*, which must become one of the permanent industrial occupations of the province of Auckland, and which will demand the sinking of a large capital in the first instance.

3. That slates similar to those of Coromandel, with associated auriferous quartzites, will be found to occur over a comparatively large area of the province of Auckland.

4. That new gold-fields remain to be discovered in that province; though experiment only, and on a suitable scale, can determine where, and whether "payable," gold-fields exist.

5. That whereas *lignites* are widely distributed over the province of Auckland, it is most desirable to ascertain whether they are of similar geological age to those of Otago, and associated with the same auriferous drifts.

6. That whereas, in Australia and other auriferous countries, gold is not confined necessarily to metamorphic slates or their derived drifts, but occurs occasion-

ally in granitic and hornblendic (syenitic) rocks or their débris; and whereas, though this is rare in New Zealand, there is, according to the testimony of Mr. Haast, the Government geologist of the Canterbury province, at least one good instance of such an occurrence in the province of Nelson (in the beds of the rivers Roto-iti and Roto-roa, where the gold could apparently only have been derived from the decomposition or degradation of rocks of a syenitic or hornblendic character);—the attention of prospectors and miners, not only in the province of Auckland, but in that of Otago and, indeed, in all the New Zealand provinces (all of which will probably be found to be to a greater or less extent auriferous), should be directed to drifts derived from granitic and hornblendic rocks, as well as to those resulting from the detrition of Silurian and other slates.

7. That it is probable the auriferous system of rocks (the supposed Silurian slates) extends from the province of Otago into the adjacent provinces of Southland and Canterbury—from Nelson (where they are already known to exist to an extent second only to that in Otago, and where, indeed, "gold-fields" have been successfully worked for a considerably longer period) into Canterbury—and from Auckland into Wellington and adjacent districts—though to what extent remains to be determined by actual survey and experiment.

8. Contrasting the Northern with the Middle Island of New Zealand, it is probable that the latter is more extensively and largely auriferous than the former; that in the former the auriferous quartzites are developed out of proportion to the derived drifts, while in the latter the reverse is the case; and that, should this supposition prove to be correct, the character of the gold-mining in the two islands will necessarily differ most materially.

9. Speaking in general terms, auriferous rocks may be said to extend throughout the New Zealand islands, the exceptions being where they are interrupted by recent volcanic formations, traps of various ages (mostly Tertiary), limestones of various ages, extensive Tertiary beds, and other geological series or systems.

The author concluded by strongly advocating the necessity of an immediate systematic *Geological survey* of the province of Auckland—one implying a duration of about five years, with an expenditure on staff, travelling, and publications of about £10,000. He recommended this equally for all the New Zealand provinces of which geological surveys have not yet been made; pointing to the example of Otago, which has recently appointed a Government geologist, who is now engaged on a three years' survey of that, geologically, most interesting province.

On the Palæontology of Mineral Veins; and on the Secondary Age of some Mineral Veins in the Carboniferous Limestone. By CHARLES MOORE, F.G.S.

The author's attention was directed to this subject by the very fissured character of the Carboniferous Limestone of the Mendip Hills, and by observing that many of the fissures had subsequently been filled with deposits containing organic remains of later geological ages, some of them being probably as young as the inferior oolite. In a quarry near one in which the author had previously found the *Microlestes*, *Placodus*, &c., there were as many as fifteen vertical fissures within a length of 200 feet, passing down through inclined beds of Carboniferous Limestone, one of them being 15 feet in breadth at the base. These contained organic remains belonging to the Carboniferous Limestone, the Rhætic bone-bed, and the Middle Lias. In the upper portions of some of the fissures, galena, sulphate of barytes, and iron-ore were present, showing that in these instances the above minerals must be of Secondary age.

In further investigating this point, the mineral deposits of the Mendips, near Charter House, were examined. In descending a lead-mine at this place, the author found the vein-stuff very varied in its character—sometimes a conglomerate, then almost composed of Encrinital stems, with a few Corals, all much abraded by the action of water; and at a depth of 175 feet a deposit of eight feet of blue marl containing 7½ per cent. of galena. In this he found about 130 species of organic remains, consisting of part of an Ammonite, Belemnites, ten species of Brachiopoda, together with numerous univalves and Foraminifera. Fish-remains were also abundant, of different species; and there were also pieces of drift-wood which had been converted into jet. It was thus evident that the Mendip lead-veins had been within the influence of the ocean during the Secondary period, and that the minerals they contained could not be of more ancient date. Somewhat similar results attended an examination of the districts around Bristol and Weston-super-Mare.

The author next examined samples furnished from six mines, in Carboniferous Limestone from Shropshire, Yorkshire, and Cumberland. From Weardale, out of twenty-seven small samples, organic remains were obtained from fourteen, the lowest being 678 feet from the surface; and the same result occurred from Alston Moor and the White Mines, Cumberland. In one small sample from the Grassington Mines, Skipton, which when washed was reduced to half an ounce in weight, not less than 156 specimens were found. These include the author's genus *Zellania*, hitherto never observed in any stratified bed lower than the middle lias; and numerous *Conodonts*, which have never been found higher than the Ludlow bone-bed.

It was argued that we had no evidence of the contents of mineral veins having been derived from volcanic agency, nor by any electrical action removing the minerals from the adjoining rock and redepositing them in the veins. The author's view was, that what are now mineral veins were once open fissures which were traversed by the ancient seas of the period, and their derived contents deposited; and that whilst these infillings were proceeding, the minerals, which might previously have been held in solution in the water, were by the operation of electrical and other causes precipitated, and that thus, instead of being due to volcanic action, they were to be attributed to aqueous and sedimentary deposition.

Contributions to Australian Geology and Palæontology.
By CHARLES MOORE, *F.G.S.*

After noticing the evidence recently obtained of the presence of Mesozoic rocks in Australia by Mr. Gregory, the Rev. W. B. Clarke, and Mr. Hood, the author remarked on the paucity of organic remains that had yet been obtained from these rocks—in the whole probably not more than thirty species. He then referred to a series of fossils he observed being exhibited at a meeting of the Somersetshire Archæological and Natural History Society, by Captain Sanford, of Nynehead, to whom they had been forwarded by Mr. Shenton from Western Australia. They appeared to have been chiefly derived from beds of oolitic age, and probably from the same district as those sent to the Exhibition by Mr. Gregory; the *Trigoniæ*, *Cucullæa*, *Belemnites*, &c., being of the same species. Captain Sanford's collection, including a number of duplicates, comprised about sixty specimens, and also a block of stone about 10 in. by 6 in., which, on being closely examined, showed that the bed from which it was derived must have been very rich in organisms; for on its surfaces the author was able to make out about thirty species, or as many as had previously been discovered from all the Australian Mesozoic deposits. It contained an Ammonite, *Trigoniæ* (allied to *T. costata*), *Pecten*, *Lima*, *Cucullæa*, *Avicula*, *Ostrea*, *Turbo*, and other univalves, *Rhynchonella variabilis*, *Pentacrinites*, &c.

Amongst the Ammonites in this collection were several allied to the *A. radians*, and appeared to indicate for the first time the presence of the Upper Lias in Australia. There were also several specimens of the *Myacites liasianus*, found only in the ironstone zone of the Middle Lias in this country; and, singularly, the matrix containing the Australian specimens yielded 52 per cent. of metallic iron.

In the absence of sections, and from the different lithological characters of the shells, the author supposed them to have been obtained from beds of different geological ages, and that, from their abraded character in some instances, they were probably found in derived deposits, and not in the parent rock; and that it was not improbable, for the same reasons, that this applied also to the other Mesozoic remains that had hitherto been found in Australia.

On the Fossils of the Boulder-clay in Caithness. By C. W. PEACH.

The author first mentioned that, as so little was known of the fossils of this formation, he thought that a short communication on the subject might be acceptable to the Section. The Boulder-clay occurs more or less all over Caithness. In some places it is very deep, especially on the banks and estuaries of rivers, sides of burns, &c., where it is found in some places to the depth of 60 or 80 feet, and at various levels up to 200 feet. In some parts it is filled with stones of various sizes. It is of different degrees of hardness; and the shells, although generally distributed, vary in number at different places, as well as the stones. The stones are all more or less striated and ground. Above the lower clay in many places are beds of sand, and from these beds wide cracks run down the clay, some vertically, others diagonally, and from these smaller cracks diverge horizontally—all being filled with sand no doubt from above, that on the sides of them being cemented together, and the centre quite loose. This sand contains organisms similar to those of the clay, but in a very friable condition. Above the sand is often seen more clay, and crowning the whole a deposit of stones derived from all the previous geological formations, some being of great size. One such, of granite, at least 30 tons in weight, near the Custom-House at Wick, is 66 feet above the level of the sea. The clay rests upon rocks grooved and polished. The grooves run about N. and S., with variations to the E. and W. Some of the shells are almost perfect, the smaller and more delicate ones being most so; others, especially the *Astartes*, are covered with their epidermis; a few are perforated, evidently by the Whelk and the boring sponge, *Cliona*. In no case had he found two valves of any shell united. A difficulty often presents itself to many on finding that although the edges of the greater part of the broken shells are rounded, others retain their sharpness, as if only just broken. This difficulty will vanish if a collection of the recent broken shells be made from the sea-shore, for there the very same appearances may be seen, agreeing in every particular with those of the Boulder-clay.

The mode of transport he thought had been by water-borne ice, the work of long periods. As he only wished to introduce the organisms, he left all this to others.

He then read a detailed list of the organisms, first observing that, as Mr. Jeffreys had kindly examined all the shells and Dr. Bowerbank the sponges, the list might be depended upon:—

Univalves.

Trophon scalariforme.
Buccinum undatum.
Nassa incrassata.
Purpura lapillus.
Mangelia Trevelliana.
—— turricula.
Natica nitida.
—— sordida.
—— helicoides.
Aporrhais pes-pelecani.
Turritella communis.
Trochus zizyphinus.
Patella vulgata.
Dentalium entale.
—— abyssorum, n. s. (Sars).

Bivalves.

Pecten maximus.
—— opercularis.
Leda caudata.
Cardium echinatum.
—— edule.
—— Norvegicum.
Cyprina Islandica.
Astarte arctica.
—— compressa.

Bivalves (continued).

Astarte elliptica.
—— sulcata.
Artemis lincta.
Tellina proxima.
—— solidula.
Mya truncata, var. Uddevallensis.
Panopæa Norvegica.
Saxicava rugosa, var.

Balanidæ.

Balanus Scoticus (porcatus).

Annelida.

Serpula vermicularis.

Polyzoa.

Hippothoa catenularia.
Membranipora ——?
Lepralia Peachii.
—— simplex.

Sponges.

Geodia ——?
Cliona celata.

Algæ.

Nullipora polymorpha (Melobesia).

Abstract.—Shells 32 species, 15 of which are Univalves and 17 Bivalves; Balanus, 1; Annelida, 1; Polyzoa, 4; Sponges, 2; Coral, 1; Alga (*Melobesia*), 1; making a total of 42 species, being the longest list of fossils ever before noticed from the boulder-clay of Caithness.

Of the shells, 29 are British, 2 Scandinavian, and 1 Arctic.

On Fossil Fishes from the Old Red Sandstone of Caithness.
By C. W. Peach.

The author introduced the subject by stating that at the Meeting of the Association at Aberdeen in 1858 he laid before the members some fishes from the Old Red Sandstone which he thought not only new to Caithness, but one of which he believed new to geology. These had since been examined by Sir P. Egerton, and figured and described in Decade X. of the Government Geological Survey. The one he had considered new, and which proved to be so, had a *true bony vertebral column*, and thus differed from the fishes of the Old Red period previously discovered. He expressed the great gratification that he felt at being relieved from the painful position of standing alone, as he had done for some years, in the opinion that true bony fishes occurred in the Old Red of Caithness. He then entered into a description of several species (fine specimens of which he laid on the table) that he had further collected, and which he considered also as new to Caithness—some new altogether; these have long lobated fins, *bony ribs and processes*, &c. One species was evidently *Gyroptychius* of M'Coy; and although some of the others belong to that genus, they are new species. In this opinion he was to a great extent supported by Professor Huxley, to whom the whole of the specimens will be sent for examination and description.

On the Correlation of the Slates and Limestones of Devon and Cornwall with the Old Red Sandstones of Scotland, &c. *By* W. Pengelly, *F.G.S.*

The distinguished author of 'Siluria,' as geologists well know, has made a tripartite division of the slates and limestones of Devon and Cornwall, as well as of the Old Red Sandstones of Scotland, &c., and given chronological equivalency to the Upper, Middle, and Lower groups of each respectively. Thus, he places the Barnstaple and Petherwin beds (the latter characterized by the presence of *Clymenia* and *Cypridina*) on the horizon of the Upper Old Red, with its *Holoptychius* and *Phyllolepis*; the limestones of Torquay, Newton, and Plymouth, in which are found *Stringocephalus, Calceola, Bronteus, Acervularia*, &c., are made to synchronize with the deposits of Caithness, &c., containing the remains of *Asterolepis, Coccosteus*, &c.; whilst the slates of Meadfoot, &c., in South Devon, and Looe, &c., in Cornwall, distinguished by the remarkable coral *Pleurodictyum problematicum*, are regarded as the equivalents in time of the Lower Old Red rocks of Forfar and the North-east Highlands, which are charged with *Cephalaspis, Pteraspis*, and *Onchus*[*].

Though this co-ordination may be said to have found a large acceptance, it is not in keeping with the opinion of some who laboured long and sedulously amongst the older rocks of Devon and Cornwall,—for example, the late Sir H. De la Beche[†] and the Rev. David Williams[‡]; nor is it unchallenged by some existing writers, amongst whom may be mentioned Mr. Page[§] and Mr. Jukes[‖].

That some diversity of opinion should exist respecting the true relations of the two systems of rocks now under notice is what might be expected when their lithological and palæontological dissimilarities are remembered. The northern beds are eminently arenaceous, whilst those in the south are almost exclusively argillaceous or calcareous; the former teem with fossil fish, and the latter with the exuviæ of molluscous and radiate animals: but, according to our fossil registers, Scotland does not yield the shells, corals, or sponges so abundant in Devonshire; nor are the ichthyolites of the former found in the latter area: they have no organic remains in common.

It will doubtless be remembered, however, that, in his 'Palæozoic Fossils of Cornwall, Devon, and West Somerset'[¶], Professor Phillips has figured and described, as a scale of *Holoptychius*, a fossil found in the slates of Meadfoot, near

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[*] Siluria, 3rd edition, p. 433.

[†] Memoirs of Geol. Survey, vol. i. p. 103.

[‡] Report of Royal Geol. Soc. of Cornwall, 1843, p. 123.

[§] Advanced Text-Book of Geology, p. 123.

[‖] Manual of Geology, 2nd edition, 1862, p. 492.

[¶] Pal. Foss. pl. 57. fig. 256, and p. 133.

Torquay, in South Devon. It would seem that this identification has not been considered perfectly reliable, since the fossil has not found a place in subsequent works on the Devonshire beds, or in Professor Morris's Catalogue of British Fossils.

The mineral and mechanical characters of the Old Red rocks may, perhaps, sufficiently explain the absence in them of mollusks and other dwellers at the sea-bottom; but there seems no satisfactory mode of accounting for the non-appearance of fishes in the slates and limestones of Devon and Cornwall. We are asked, by one proposed solution of the problem, to suppose that some geographical difficulty or barrier separated the two areas and prevented the migration and mingling of their inhabitants; whilst another suggests that the Old Red fish were probably at home in fresh water only, and ought not to be looked for in beds so decidedly marine as those of Devon and Cornwall.

The interesting and important discovery, by Sir R. I. Murchison [*], of the intermixture, in the same Devonian bed in Russia, of the fish of the Upper and Middle Old Red of Scotland with the shells of Devonshire seems to dispose of the latter of the two proposed solutions just mentioned, but leaves the difficulty untouched; nor does it appear that the synchronism of the representative beds in Britain necessarily flows from it. It proves, of course, that the fish and shells lived at one and the same time in Russian, not that they did so in British, waters. We may have an example here of the distinction between geological *contemporaneity* and *synchrony*, so ably pointed out, on a recent occasion, by Professor Huxley [†].

At the Meeting of the British Association held at Cork, in 1843, Mr. Peach brought under the notice of the Geological Section certain fossils which had then recently been found, by Mr. Couch, in the Devonian slates of Polperro, in Cornwall. The palæontologists to whom they were then submitted considered them to be the remains of fishes; this was the opinion also of the late Mr. Hugh Miller at first, but subsequently he considered them to be very doubtful and extremely puzzling; ultimately they were pronounced, by Professor M'Coy and Mr. Carter, of Cambridge, to be sponges merely. It may still be doubted, however, whether certain fossils found with them were not true ichthyolites; indeed, one specimen which, a few years since, I found in the same beds at Looe, in Cornwall, has been pronounced by Sir P. Egerton and others to be a decided ichthyodorulite [‡]. It has not been identified, however, even generically.

A few weeks since, I had the good fortune to find a fossil in the *Pleurodictyum* slates at Meadfoot, near Torquay; that is, in certainly the lowest group of the rocks of South Devon, and which Sir R. I. Murchison has placed on the horizon of the *Cephalaspidian* and *Pteraspidian* beds—the lowest of his divisions of the Old Red of Scotland. The fossil was at once identified by Mr. Davies, of the British Museum, as a scale, or rather a portion of one, of *Phyllolepis concentricus*, Agass.—a fish known only by its fossil scales, which have hitherto been found only in the Clashbinnie beds, belonging to Sir R. I. Murchison's "Upper Old Red."

This fossil, then, appears to necessitate the belief, either that the organism which it represents had a greater vertical range than has been supposed (that is, that it belonged to the Lower and Middle, as well as Upper, Old Red fauna), or that the *Pleurodictyum* beds of Devon and Cornwall, instead of being on the horizon of the Lower, are on that of the Upper Old Red Series of Scotland.

To accept the first of these (apparently the only two) alternatives would be to accept the difficulty of supposing that *Phyllolepis* dates from the times of *Cephalaspis*, the extinction of which it witnessed, as well as the subsequent introduction and withdrawal of *Coccosteus*, *Asterolepis*, and others; and yet that, unlike its early contemporaries, it failed to leave any trace of its existence in the Old Red rocks, save only in the uppermost of their three groups.

Rejecting this, however, we seem compelled to adopt its rival, which amounts to this:—There are in Devon and Cornwall no representatives of the Lower and Middle Old Red rocks of Scotland, but the Lowest (the *Pleurodictyum*) beds of the former are on the horizon of the upper division of the latter,—an opinion in harmony with those of Sir H. De la Beche and the Rev. David Williams, already spoken of, as well as that advocated by myself in an earlier paper*. It will be seen also that the indications of the supposed scale found by Professor Phillips were to the same effect. Like the Old Red Sandstone fish found in Russia by Sir R. I. Murchison, the *Phyllolepis*-scale was surrounded with marine shells†, and also by corals; hence the ancient fish to which it belonged was not incapable of living in the sea.

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[*] Siluria, 3rd edition, p. 382.

[†] Anniversary Address, Quart. Journ. Geol. Soc. vol. xvii. p. 40, &c.

[‡] See 'Geologist,' vol. iv. pl. 6, p. 346.

On the Gold-bearing Strata of Merionethshire.

By T. A. Readwin, *F.G.S., F.S.S.*

The author referred to a paper read before the Association at Manchester in 1861, the object of which, he said, was to point out the probability of gold-seeking in the Dolgelley district being, at no very remote date, of commercial importance. He stated that, since the last Meeting, he had acquired additional facts connected with the subject, and his wish was to present them in support of the opinion expressed in the paper referred to.

The author said that he had employed an eminent analytical chemist for several months upon the spot, to test the accuracy of his former experiments; and the assays referred to in the paper were made of 8000 grains, taken from quantities of 56 lbs., after the most careful sampling, instead of the customary 400 grains.

He said that the geological features of the district were now too well known to require more than a repetition of the general statement that the rocks are of the Cambrian and Lower Silurian series, forming a junction in a very sinuous course, and frequently cut through by narrow bands of porphyritic greenstone.

The metalliferous veins have a general bearing N.E. and S.W., with an underlie to the north.

The auriferous district under notice is comprised in the Ordnance Survey Maps, 75, S.E., and the upper part of 59, N.E.

For convenience, he divides the district into the following sections:—Cwmheisian, Maesgwm, Berthwllyd, Cambrian, Clogau, and Vigra.

The parishes included in the notice are Llanfachreth, Trawsfynydd, Llanddwye, Llaneltyd, and Llanaber.

The Cwmheisian Section.

The *Cwmheisian uchaf Mine* has in it more than twenty strong metalliferous lodes. One very remarkable junction of about fourteen lodes is 40 feet wide, and the whole of this mass of lode-stuff contains more or less gold.

A large number of assays gave from 3 to 19 dwts. of gold to the ton of quartz. Picked specimens of galena have given as much as 16 ounces to the ton; and more than 170 ounces of gold were taken by Mr. Clement from about 300 tons of mineral from all parts of the mine. Mr. Arthur Dean produced 148 ounces from 157½ tons of ore. Gold, visible in blendic quartz, has been discovered within the last month.

Cwmheisian Isaf is a silver-lead mine, adjoining the last-mentioned on the south. The galena yields about 47 ounces of silver to the ton; and one lode in the mine gives, on assay, 5 to 11 dwts. of gold to the ton of mineral.

Gwynfynydd Mine is opposite Cwmheisian Ucha, on the west bank of the river Mawddach. Galena from this mine, though poor in silver, has occasionally given as much as 8 ounces of gold to the ton.

Hafod-y-bach Mine.—Samples of quartz, indiscriminately taken from this mine, gave from 3 to 5 dwts. of gold to the ton. The mineral here is probably richer than this.

Tyddynglwadis Silver-Lead Mine is on the west bank of the river Mawddach, about eight miles from Dolgelley, in the direction of Tanybwlch. This mine is situate exactly at the junction of the Cambrian and Lower Silurian rocks, which is distinctly observable at the top of the charming waterfall, Pistil-y-Cain.

The average quantity of silver contained in the galena is from 50 to 60 ounces to the ton. Selected specimens have given as much as 300 ounces. Visible gold is occasionally found in the galena, and he had seen it also in copper-pyrites.

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* Report of the British Association, 1860, p. 100.

† Siluria, 3rd edition, pp. 383 and 433.

Assays for gold gave from 6 to 11 dwts. per ton. Some moss pulled from the river-side had small specks of gold attached to the roots.

Penmaen Copper Mine has some very strong metalliferous veins upon it, said to be auriferous. Visible gold is said to have been found here.

Dolfrwynog Gold Mine is situate about a mile over the mountain eastward from Cwmheisian, and includes the farms denoted on the Ordnance Map—Dolfrwynog, Tynsimna, Bwlchroswen, and Rhoswen. This is a very remarkable property. There are several strong lodes, only one of which he notices in the paper: it is known as the "Gold Lode." He had stones of beautiful quartz from this lode, containing at least 400 ounces of gold to the ton!; and he believes that a goodly amount of gold will be obtained from this lode, although it underlies north 6 feet in a fathom, and at the depth of about 60 fathoms enters a spur of the North Dolfrwynog Mine. He had specimens from this lode in the International Exhibition, and had seen stones taken from a depth of nearly 40 fathoms, richer than any at Clogau. The bulk of this lode-stuff will give on an average, he thought, from 10 to 15 dwts. of gold to the ton.

East Dolfrwynog Mine is on the east of the last-mentioned, and takes in the farms marked on the Ordnance Map—Buarthrae, Doledd, and Penbryn. There are six or more lodes on this property, which give on assay from 6 to 9 dwts. of gold to the ton.

The Dolfrwynog Gold Lode runs into Penbryn—a few yards from the spot, at Dolfrwynog, where the richest gold was discovered. It is about 5 feet wide, and of precisely the same character, and will probably prove as rich.

North Dolfrwynog Gold and Copper Mine is situate on the east bank of the Mawddach. There are ten metalliferous veins in this property, and all of them auriferous. The Dolfrwynog rich Gold Lode underlies into this sett; and it is certain that at the depth of 60 fathoms very rich gold will be found.

Assays of the lode-stuff from this mine give an average of 9 dwts. of gold to the ton.

The author said that he had once extracted as much as 6 ounces to the ton from stuff in which gold was not detectable under a powerful microscope. He had recently superintended the removal of about 100 tons of alluvium from the eastern bank of the Mawddach, with the object of discovering whether the particles of gold found therein increased in size from the surface to the bed-rock. He found this to be the case; and the sample of coarse-grain gold produced was perhaps the most interesting item of the recent discoveries. This gold was obtained by a very rough washing over a trough 30 feet long,—a process which washed away all the fine gold, weighing probably ten times as much as the coarse gold obtained. It is probable that the whole side of this mountain will be found to contain gold in paying quantities on the erection of machinery to economize labour.

West Dolfrwynog Copper and Gold Mine adjoins the last-mentioned on the south, and is marked on the Ordnance Map the "Turf Copper Mine," from the singular fact that, some time ago, about £10,000 of copper was sold from the ashes of peat, there burnt for the purpose. The water at the present time is highly saturated with copper; and a shaft, now in course of sinking, will probably discover a large deposit of copper-ore, if not gold.

The lode-stuff of this mine gives on assay about the same quantity of gold as North Dolfrwynog. On a portion of the mine the author found the alluvium to contain gold under the same circumstances and in about the same proportions as the North Dolfrwynog Mine. Gold has been obtained here at the rate of 6 ounces to the ton. The minerals of this mine and Dolfrwynog are identical in character.

THE MAESGWM SECTION

Is on the western side of the Trawsfynydd Road, nearly opposite Tyddynglwadis.

Maesgwm Mining Sett extends over 1600 acres, and has three large lodes on it, which are all auriferous.

The Cwmheisian Great Gold Lode runs into it, and the Ganllwyd Gold Lode.

Ganllwyd Gold Mine has two very distinct lodes, from one of which he had taken several stones of visible gold. The poorest stuff contains on assay 10 to 11 dwts. of gold to the ton. This mine will probably prove a second Clogau, as the lode-stuff is identical in character with the Saint David's Lode.

Coed-cy-fair Mine is S.W. of Maesgwm, and has the same surface appearance. Visible gold has recently been found here. Assays have given 3 to 5 dwts. to the ton from surface quartz.

THE BERTHWLLYD SECTION.

Berthwllyd Mine is situate on the summit of the precipitous and lofty ridge of hills to the west of the curious little roadside inn, the "Oakley Arms," at Tyn-y-groes, on the Trawsfynydd road from Dolgelley.

There is what Mr. Warington Smyth appropriately calls "that grand champion lode Berthwllyd," which runs in a direction N.N.E. and S.S.W. for about a mile. Blende and galena are the chief products of this mine, all of which are auriferous.

Only a few days ago, the author saw both blende and galena pounded fine, and gold washed therefrom, in the proportion of 3 to 4 ounces to the ton. He himself washed gold from the alluvium of so fine a quality that it floated on water.

As much as 6 ounces to the ton has recently been extracted by Britten's amalgamating-machine. This mine is destined to produce, he thinks, from its inexhaustible supply of metalliferous quartz, some extraordinary results.

Goitref Mine adjoins the last, the quartzose lodes of which are auriferous.

Caegwernog Mine adjoins Berthwllyd, and is favoured with a continuation of the Great Champion Lode at Berthwllyd. Trials of ores from this mine have produced sometimes as much as 8 ounces to the ton. A few days ago, the author visited the spot for the first time, and discovered an old heap of calcined stuff upon which were visible globules of gold. Assays of the surface lode-stuff produced from 2 to 4 dwts. to the ton.

Cae Mawr Mine adjoins the Berthwllyd and Caegwernog Mines. It was here that the first gold was discovered. Visible gold has recently been found. Assays give from 9 to 11 dwts. to the ton of surface mineral.

Gold is also found in the alluvium, by washing, in about the same proportions as at North and West Dolfrwynog.

Benrhos Mine.—The alluvium here contains specks of gold, similar to the last-mentioned.

Tyny-benrhos Mine adjoins the last, and contains gold in the alluvium, as above.

Glasdir Copper Mine, to the N.E. of Tyny-benrhos, is a very remarkable property; £15,000 worth of copper-ore has been sold from this place, simply the result of quarrying. Very rich gold-stones have been found here, some of which the author had seen.

THE CAMBRIAN SECTION.

This section extends along the north side of the turnpike-road from Dolgelley to Barmouth.

The *Cambrian Gold Mine* has six remarkable blende lodes, three of which the author knows to be highly auriferous. No. 6 lode produces gold occasionally very rich in blende. He had himself extracted gold from the blende-ore, at the rate of 300 ounces to the ton. There can be no question about gold being found here in paying quantities. Very rich ore has been recently raised. One large specimen contained gold in the slate. A very rich specimen was exhibited.

The *Cwmabseifian* (East Clogau) *Mine* is situate to the north of the Cambrian Mine. The noticeable lode in this sett is one that has the appearance of being a continuation of the Saint David's Lode at Clogau. The quartz is similar, and contains gold on assay. Mr. Clement's analysis gives 18 dwts. 14 grs. to the ton.

The *Princess Alice Mine*, situate between the Cambrian and the Prince of Wales Mines, has given gold on assay at the rate of 8 dwts. to the ton. The lode-stuff has the same character as the Cambrian. The author extracted gold from it in 1856.

Moel Ispri Mine, on the N.E. of the last, has yielded, it is said, at the rate of 8 ounces of gold to the ton of galena.

The *Prince of Wales Mine* is on the east of the Princess Alice. It has several remarkable galena and blende lodes. Some specimens from this mine in the author's case at the International Exhibition contain from 300 to 400 ounces of gold to the ton. The lode-stuff will probably yield as much on the average as the Saint David's Lode at Clogau. Seventeen ounces of gold were recently obtained from 5 cwt. of blende ore. A very rich specimen was exhibited.

THE CLOGAU SECTION.

The now celebrated *Clogau Gold Mine* is situate about a mile and a half north of the "Halfway House," on the turnpike-road from Dolgelley to Barmouth, the most charming road in Europe.

This property contains a large number of lodes, mineralized throughout more or less with galena, blende, and copper-pyrites, and with the occasional occurrence of bismuth and tellurium.

The *Saint David's Gold Lode* is the most noted, in consequence of its having outstripped all other gold-mines of the kingdom by doing the last thing that was predicted of it, namely "pay a profit." Of this, however, there can be but little doubt, as, by official returns up to the 30th September last, 7892 ounces of gold have been sold to the Bank of England, the produce of only 1091 tons of quartz!—1173½ ounces of which were produced from 1072½ tons of mineral in which the gold was not visible, and the astonishing quantity of 6718½ ounces from only 18 tons 17 cwt. 3 qrs. 14 lbs. of quartz, realizing nearly £30,000, at a cost of some £3000, or less! No quartz-mining on record has given such a result. This remarkable lode produces gold in quartz, in the 15-fathom level, at the rate of an ounce to the ton.

The author stated that, in his paper of last year, he had placed on record the product of the first *hundredweight* of Welsh gold. He had now to record more than *four hundredweight*; and he believed the mine, under proper management, to be capable of producing far greater results than those just mentioned.

A bar of gold weighing 37 ounces, part of the produce alluded to, was exhibited, and a chain of pure gold, manufactured by Messrs. Watherston and Brogden.

The first three quarters of the year 1862 show the following result:—

tons.	cwt.	qrs.	lbs.		ozs.	dwts.	grs.	
789	18	0	0	of poor ore have yielded	739	19	0	of gold.
13	16	1	12	of rich ore have yielded	4566	2	12	of gold.
803	14	1	12	crushed. Total . .	5296	1	12	

—which is equal to 18 dwts. 13 grs. per ton from the former, and 330 ozs. 9 dwts. from the latter, or an average of 6 ozs. 12 dwts. per ton from both. The gold brought £3 17*s.* per ounce, after deducting expenses for realizing same; nett. £20,390 15*s.* 5*d.*

The *Garthgell Mine* is situate between the Cambrian and Clogau Mines, and receives the lodes of both mines. The Cambrian Gold Lode runs into the sett a few yards from the spot where visible gold is now being raised, and the Saint David's Gold Lode has been traced on the Clogau side up to the boundary of the Garthgell Sett. The same results as the Cambrian are expected daily. The ores by assay give from 2 to 10 dwts. of gold to the ton at surface, and, to appearance, increase in depth. A shallow adit will cut the Cambrian Gold Lode at about the same level as that company's present working.

Tynycornel Farm, on the west of Clogau, has the Saint David's Lode running through it. This is at present unexplored; but as the lode on each side of the farm is auriferous, it is more than probable that gold will be found here also.

Hendreforian Mine lies in the middle of the Hirgwm valley, between the Vigra and Clogau Mountains. Gold has been produced here by assay. The indications here are good.

West Clogau Mine, at Llachfraith, has yielded from a ton of quartz 17 dwts. of fine gold—about half, probably, of what it contained, when the means used to extract it are considered. The author found gold visible in the quartz here in 1856, at nearly 150 fathoms lower than the upper level at Saint David's Gold Lode.

THE VIGRA SECTION.

The *Vigra Copper Mine* is situate to the west of Clogau, and takes up nearly the whole of the Vigra Mountain. Extensive explorations have been carried on here for copper, some of which is auriferous. The lode-stuff, taken at random, yields nearly half an ounce of gold to the ton, on assay. Specimens have produced more than this. Visible gold is said to have been found here. This mine ought to be worked on a large scale for gold. The Clogau Gold Mill is erected on this property.

Tyddyndu Mine, or as it is called "Victoria," lies between the Vigra and Clogau Mines, to the south of Maesclawdd, and extends under the turnpike-road at Pontddu to the river Mawddach. There are several lodes on this property, all of which are auriferous. At present they are poor at surface.

North Vigra Mine has several lodes, said to be gold-bearing.

The *Wellington Mines* have some very large quartzose lodes in them, which are undoubtedly auriferous.

Fach-ynys Mine.—The lodes here have yielded 6 dwts. of gold to the ton at the surface. This mine promises to be rich.

Nant-Coch Mine has given by assay, and, singularly enough, by Britten's Machine, 9 dwts. 13 grs. of gold to the ton of mineral.

Llanaber Mine, near Barmouth, is also auriferous at surface.

The known gold localities are now multiplied; and the author added, that he should not be at all surprised if every quartzose vein of the district is found to be auriferous, but that it must by no means be inferred from this that every quartz-lode will pay for working: some will not; but where there are so many, some certainly will prove rich.

Having said thus much upon the increased number of places in which gold is found in this district, the author made some reference to the modes of gold-extraction now in operation.

Notice of some Mammalian Remains from the Bed of the German Ocean.

By C. B. ROSE, *F.G.S., &c.*

It has for a very long period been known that, during the degradation of the cliffs of the counties of Norfolk, Suffolk, and Essex, teeth and bones of various mammals have been exhumed, and, more largely, those of Pachyderms. In Queen Elizabeth's time, huge bones were found at Walton, near Harwich. They were then considered to be those of giants. In the 'Philosophical Transactions' for 1745, a Mr. Baker records the finding of a fossil elephant at Mundesley Cliff; and, in 1746, Mr. Wm. Arderson, of Norwich, makes mention of similar remains discovered at Hasborough and Walket, on the Norfolk coast.

In the course of years, vast numbers of teeth and bones have been collected. The late Mr. Woodward, of Norwich, says, in his 'Geology of Norfolk,' "Mammalian remains have been dredged up on the Knole Sand off Hasborough. This spot presented us, in 1826, with the finest tusk of the Mammoth; it measured 9½ feet along its curvature, and weighed 97 lbs." But off Dungeness a tusk was dredged up which measured 11 feet in length, and yielded some pieces of ivory fit for manufacture. The oyster-bed off Hasborough was discovered in 1820, and, from the number of grinders of the Elephant found there, Mr. Woodward felt himself warranted in concluding that upwards of 500 animals were deposited in that limited space.

The coloured map of the German Ocean exhibited at the Meeting showed the localities whence the organic remains are chiefly taken. Certain spots marked thereon are the fishing-grounds, and, therefore, the depositories of the fossils with which we are made familiar; but we cannot doubt that these exuviæ are more generally distributed over the sea-bottom. The following specimens were exhibited:—Teeth of three species of Elephant, *Elephas primigenius*, *E. antiquus*, and *E. meridionalis*; cervical and dorsal vertebræ of the same genus; two teeth of a Hippopotamus (a dorsal vertebra has since been brought up); a dorsal vertebra of a Whale; a unique specimen of a lower jaw of the *Trichechus rosmarus*; heads of the *Megaceros Hibernicus*, male and female; an anterior dorsal vertebra of ditto (an antler, 4 feet 6 inches long, has since been brought me); atlas of ditto; a fragment of an antler of *Cervus tarandus*; the humerus of a gigantic Ox; a portion of the head of the *Equus fossilis*; and a fine specimen of *Castor Europæus*—the head. The colour of these specimens might lead us to believe that they belonged to the Mammaliferous Crag period; but colour is not a decisive criterion. It is probable that they may have lain in close proximity to a bed of crag*; they are unquestionably from a Pleistocene deposit.

And now as to how these organic remains came to be at the bottom of the ocean. At a not very remote geological period our island was united with the Continent; a catastrophe took place which separated them and led to the formation of the German Ocean. This gap has been continually enlarging, from the crumbling down of the cliffs on either side; the fossils have thus been exhumed, carried out to sea during storms by retiring waves, and there deposited. No doubt, also, many remains which lie buried in the land that originally united us to the Continent sank bodily with it; and consequently they are met with when the sea-bottom is raked over by the trawling-nets of the fishermen.

The measurements of three tusks are given. One, belonging to Mr. Owles, measures: length of external curve 7 feet 5 inches; girth at proximal end 18 inches; radius of inner curve 3 feet.

The author possesses two perfect tusks: one, length 6 feet 3 inches; girth 17 inches; radius of curve 3 feet 3 inches: the other, length 6 feet; girth 12½ inches; radius of curve 4 feet 2 inches. These proportions indicate that his specimens are from two distinct species of Elephant.

A femur of the Mammoth in his possession measures 3 feet 5 inches, minus the head of the bone.

On the Identity of the Upper Old Red Sandstone with the Uppermost Devonian (the Marwood Beds of Murchison *and* Sedgwick*), and of the Middle and Lower Old Red with the Middle and Lower Devonian.* *By* J. W. Salter, *F.G.S.*

The sections of the Old Red Sandstone and Mountain Limestone on the Pembrokeshire coast are unrivalled for their extent and completeness. The vertical beds, exposed to the coast-waves, are worn by them in such a manner as to clear them of all detritus, and exhibit the succession of Old Red conglomerates, Carboniferous shales, and Mountain Limestone in several small sandy inlets accessible at all tides, especially at the most important points, viz. the junction of the Old Red with the superjacent shales.

Three of these sections have been measured in detail by Sir H. De la Beche and the corps of the Geological Survey, and are given in vol. i. of their Memoirs, pp. 61, 100, 130.

At Caldy Island, the Upper Old Red marls and sandstones, ending in yellow conglomerate-beds, are covered by 400 feet of shales and limestones in an alternating series, among which beds of oolite were found to be of common occurrence, filled, down to the very base, by common Carboniferous species,—a thin band (at the base only) exhibiting, on the west side of the island, a bed of undescribed bivalve shells, all, however, *allied* to Carboniferous forms. And a new fact was established during this survey, viz. the presence of a band of marine Serpulæ 40 feet down in the Old Red.

The same section, bed for bed, with the characteristic thin oolite bands, and beds of shale crowded with the *Rhynchonella pleurodon*, occurs on the opposite coast of Skrinkle Bay, another of the sections measured by Sir Henry and his assistant Mr. Ramsay.

About twenty miles to the westward, the small bay of West Angle opens at the mouth of Milford Haven; and here a sharp, faulted synclinal in the middle of the bay permits the whole section to be seen twice in the promontories and reefs on either side of the bay. The series of beds have changed considerably from that seen on the opposite coast, and nearly 150 feet more shales are added to the upper part. In these shales a very perfect cleavage is established, fully justifying the term "Carboniferous slate" applied to this formation in Ireland by Sir R. Griffith. It is the lower limestone shale of Dr. Smith, as seen at Bristol and the Mendips. In this section, too, new bivalves occur in the basement-beds as at Caldy Island.

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* The atlas of the *Megaceros* has a *Turritella incrassata* (Crag fossil) sticking in the canal for the vertebral artery.

Sundry other changes are observable when this section is compared with that on the east coast. The yellow conglomerate has disappeared; and while red and grey conglomerate-beds are still plentiful on the north side of the bay, on the south side (a distance of barely a mile) scarcely a band of conglomerate can be traced in the first 80 or 90 feet, only 25 feet of which is of a red colour at all; the remainder consists of grey shale, yellow sandstone, and bands of limestone, which have only the faintest representatives on the north side. Grey shales, with plants, are mixed with these on both sides.

The limestones are nodular, and contain crowds of *Avicula Damnoniensis*, Sow.: the characteristic shell of the Uppermost Devonian beds north of Barnstaple, North Devon (*Rhynchonella laticosta*, Phill.), occurs with it, together with species of *Nucula*, *Axinus*, *Modiola*, and *Bellerophon*, all of which are closely like, if not identical with, Barnstaple species. The *Serpula*-band before mentioned, at Caldy Island, occurs among these limestones, and at a somewhat greater distance below the base of the Carboniferous shales.

By this remarkable change in the mineral character, accompanied by the introduction of a marine fauna, we are prepared for the still greater change in the Old Red sediments on crossing the Bristol Channel. The red tint is not, indeed, wholly lost between Ilfracombe and Barnstaple, but is confined to a narrow belt of rocks; and the Marwood beds, which are the equivalents of the uppermost red rocks of Pembrokeshire, are grey sandstones and olive shales, with calcareous bands, and with no red colour at all. They represent exactly the state of things (but on a much larger scale) above described on the south side of West Angle Bay.

The Marwood Sandstones form a conspicuous group, ranging along a line five miles north of Barnstaple, and traceable east and west. They are well exhibited in the quarries at Sloly, on the Ilfracombe Road, at Marwood, Braunton, &c., and they form the headland of Baggy Point, where the best section occurs.

In ascending order we have the—

1. Red slates and sandstones of Morte Bay.
2. A band of pale, nearly white slate, with a few bivalves.
3. A thick series of greenish-grey grits, with bands of *Cucullæa* and *Avicula Damnoniensis* in abundance, and with much olive shale, in which a new *Lingula* occurs plentifully. (Marwood beds.)
4. An alternating series of calcareous sandstones, grey shales with thin nodular bands of limestone, and grey cleaved slate, full of fossils, and many hundred feet thick; *Avicula Damnoniensis*, *Rhynchonella laticosta*, &c., in all the lower part, and *Strophalosia caperata* and *Spirifer Barumensis* throughout. (Pilton Group.)

This series (No. 4) is the upper part of the Pilton group of Professor Phillips, and its aspect in the grand coast-section is exactly that assumed by the Carboniferous shales which lie upon beds much resembling No. 3 (and with the same fossils) in the West Angle section. The author had previously suggested this explanation (see Address of Pres. Geol. Soc. 1855, p. xlviii). A more minute comparison of the two series convinced him that this identification (strongly advocated by Sir H. De la Beche) was erroneous, and that the Pilton group really represents a new series, including in an altered form the uppermost beds of the Old Red Sandstone*, together with certain beds at the very base of the Carboniferous shales. But in the main it is a new series, deposited in deepening water, while the Upper Old Red area was stationary (or nearly so) and close to shore, as evidenced by its plants. This series of beds has been described from the South of Ireland, by Professor Jukes and the author, under the term Coomhola Grits. It occupies there the same relative position, overlying the true Old Red beds, and underlying the mass of the Carboniferous slate.

Some of its fossils are Carboniferous species; but most of them, though strikingly similar, are not identical, and the presence of a common Devonian Trilobite throughout confirms the propriety of their first reference by Murchison and Sedgwick to the top of the Devonian system. The Boulogne beds chiefly belong to this series, as does the "*Spirifer-Verneuili*-schiefer" of the Prussian geologists.

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* Siluria, 2nd edit. p. 300.

It is overlain, along the course of the Barnstaple River, by the representative of the Carboniferous slate, and this again by the Mountain-limestone series in a greatly altered form.

The Marwood and Pilton group, at least in part, can be thus proved by fossils to be the actual equivalent of the Upper Old Red Sandstone, a formation which has been found in some parts of the British Isles to be unconformable on the Lower Old Red Sandstone.

The identification of this Old Red Sandstone with the Devonian beds has been a point hitherto singularly destitute of proof, though its suggestion by Lonsdale, and subsequently by Austen, Sedgwick, and Murchison, in memoirs on Devonshire and on the Rhine, has been generally approved.

So little proof existed of this identity, that one of our best observers, whose research had largely tended to the establishment of the Devonian series (Mr. Godwin-Austen), has recorded his doubts in the Geological Society's Journal (vol. ix. p. 231), identifying the Old Red Sandstone only with the *uppermost* or Marwood beds, which Mr. D. Sharpe considered as Carboniferous; while Mr. Sharpe himself placed the Old Red Sandstone at the *base* of the Devonian system (vol. ix. p. 20, &c.).

The fossil clue has once more unravelled a geological difficulty. Sir R. I. Murchison, in reclassifying the beds of the Old Red Sandstone of Scotland (Siluria, 2nd edit. p. 285), has shown good reason for considering the order of superposition to be as follows:—from the base,—

1. Lower Old Red, with *Cephalaspis*, *Pteraspis*, *Pterygotus*.
2. Middle Old Red, with *Coccosteus*, *Diplopterus*, *Osteolepis*, *Pterichthys*, &c.
3. Upper Old Red, with *Holoptychius*, *Glyptopomus*, &c.

The Upper Old Red, then, being identical with the *uppermost* Devonian, it remains to be seen if we can find fossil links between the middle and lower members of each respectively.

It has been repeatedly shown that *Coccosteus*, a fish characteristic of the *middle* Old Red beds, occurs in the Eifel and the Harz, in strata which belong to the Middle Devonian; and in Russia* it is common to have this and other genera (*Asterolepis*, *Dendrodus*, &c.) in beds of sandstone intercalated with the marine shells.

There is still the *Lowest* Devonian zone, viz. the Spirifer-sandstone of the Rhine. The lower sandstones and slates of Linton, in N. Devon, and of Fowey and Torquay, in S. Devon, are its equivalents. In order to prove this zone identical with the lowest Old Red—the Cornstone group, it was needful to find some at least of the characteristic fish in it. In no Old Red locality have we any marine fossils mixed with the *Cephalaspis* and *Pteraspis*; but in one of the German localities Prof. Rœmer has lately discovered, and Prof. Huxley described (Quart. Journ. Geol. Soc. 1861), a large species of *Pteraspis*—a fish so exclusively characteristic of the lowest Old Red as to leave no doubt whatever of the true correlation of the two deposits.

Upper, Middle, and Lower Old Red are, therefore, now linked in all their parts by fossils with Upper, Middle, and Lower Devonian.

On a Skull of the Rhinoceros tichorhinus. *By* S. P. SAVILLE.

On a Whittled Bone from the Barnwell Gravel. By H. SEELEY, *F.G.S.*

This was the proximal end of a dorsal rib of a large mammal, seemingly the Elephant, obtained by the Rev. F. J. Blake from the gravel-pit at Barnwell, near Cambridge. The specimen shows on the severed end numerous cuts, as though made to assist in breaking the bone. The author urged that, as the condition of the cut surfaces was like the external surfaces—as they had passed unnoticed till he detected them—as similar cuts could not be made on fossil bones without great care and chemical preparation, and there was nothing to suggest a doubt as to their authenticity, the cuts were as old as the date of fossilization. And as bones are there only found in one band of loam, it was further urged that they might be taken as evidence of the coexistence of man in that district with the Irish Elk, *Bos primigenius*, *Elephas primigenius*, *Hippopotamus major*, and the other mammals of the gravel.

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* Siluria, 2nd edit. p. 382, 421, &c.; see also vol. xv. p. 437.

On a Successful Search for Flint Implements in a Cave called "The Oyle," near Tenby, South Wales. By the Rev. Gilbert N. Smith.

This is a cave in the mountain limestone, about 70 feet above the level of the valley beneath, up which the tide has till very recently been used to flow.

Within, it is distinguished by chambers, alternating with narrow passages, penetrating 30 or 40 yards into the spur of a ridgeway of the Old Red.

Floor not more than 3 feet deep anywhere, and bearing traces at the sides of a stalagmite covering long since destroyed.

Seventy-three artificial flakes or chips were unearthed, *together with the identical lumps of flint which remained after the chips were struck off, when, from their reduced size, they were no longer capable of yielding flakes sufficiently large to answer the destined purpose.*

Some of the chips are of ordinary flint; some of a dull green, opake chert. In size they vary from about 4 inches in length to half an inch. In general form they are almost identical with the flakes found at Red Hill. They were disseminated through the soil of the whole cave, but much the most thickly scattered on the floor of a recess near the entrance.

Interspersed also with them through the soil, which in some places is nearly black, were a great many bones. Most of these belong to such ruminants as are now domesticated. Some are of the usual cave-mammals, as *Ursus spelæus*, &c. One very fine front *prong* of an antler lay by itself in black earth, and has marks as of a tool. Length 11 inches; circumference at base 4½ inches.

The *lowest* portion of the soil seemed quite undisturbed, down to the rock. It is similar to the drift around the cave. Plenty of edible-mollusk shells occurred intermixed.

The investigator believes these flints to belong to the same human family that raised seven or eight tumuli which exist above on the ridgeway, which *contained flint arrow-heads* and a central kist vaen, or covered cromlech.

He is of opinion that these flakes are the neglected refuse of the workshop, there being no *perfected* flint arrow-heads among them, like those in the barrows, though there are *eight broken pieces of perfected ones* among the seventy-three specimens.

The Welsh antiquaries here do not find mention of any weapons of stone among their ancient writings, except for sacrificial purposes,—in accordance, this, with Joshua v. 2, where flint knives are prescribed to circumcise, which Lightfoot says was a kind of *sacrifice* also. The most eminent Welsh scholars have been consulted by the writer.

There is no flint in the strata of this neighbourhood; and the chert, which has small white spots through it, and looks more like some fine kinds of trap, does not appear in the coast-strata, although sea-borne boulders of granite and an occasional flint may be picked up, with here and there a worn fragment of serpentine and iridescent plutonic rock.

On the Cause of the Difference in the State of Preservation of different kinds of Fossil Shells. By H. C. Sorby, *F.R.S., &c.*

The fact of certain kinds of fossil shells having lost their organic structure, or being entirely removed, whilst in the same bed other kinds remain almost in their original state, cannot fail to have attracted the attention of most geologists. For example, most univalve and such bivalve shells as *Trigoniæ*, and the inner layer of *Aviculæ* and *Spondyli*, are often altered or removed, though their outer layer and the entire shells of *Ostreæ* and *Brachiopoda* are well preserved. After having made a considerable number of experiments with recent and fossil specimens, the author had come to the conclusion that this difference was due to the original difference in the state of the carbonate of lime; and that, other conditions being the same, shells which were composed of calcite are preserved, whereas those composed of arragonite have been altered. This appears to depend on the fact of the particles of arragonite being in a state of unstable equilibrium. When prepared artificially, it has a great tendency to pass into calcite; and if this change took place in shells, their organic structure would be very apt to be destroyed, though the shell might remain as a crystalline mass of calcite. If, however, the circumstances of the case were such that the calcite formed at the expense of the arragonite of the shells had a greater tendency to crystallize elsewhere rather than *in situ*, they would be removed, and leave more or less perfect casts. On the contrary, calcite having no such tendency to change, shells composed of it might, under similar conditions, remain nearly in their original state.

On the Comparative Structure of Artificial and Natural Igneous Rocks. *By* H. C. Sorby, *F.R.S., &c.*

As is well known, Sir James Hall and Gregory Watt, by fusing and slowly cooling basalt, obtained a stony mass, to a certain extent similar to the original rock. Various writers on the subject have since contended that the product is not, like the original, composed of several distinct minerals, but made up of only one kind of crystals. The author, however, showed that, when thin transparent sections are examined with a high magnifying power, it may be seen that the artificial rock is really an aggregate of the three principal minerals of the original basalt, which, nevertheless, are developed and arranged in such a very different manner that it is easy to understand why this fact has been overlooked. Indeed, the difference in general structure is so considerable that, probably, other causes besides a slower cooling were instrumental in producing the peculiar characters of the natural rocks.

On Scutes of the Labyrinthodon, from the Keuper Bone-Breccia of Pendock, Worcestershire. *By the* Rev. W. S. Symonds, *M.A., F.G.S.*

The remains of this Triassic reptile have been found in the Keuper sandstone of Warwick and Leamington, but had not hitherto been detected in the Trias of Worcestershire or Gloucestershire. The scutes and bones found by Mr. Symonds were submitted to Prof. Huxley. They occur chiefly in the "bone-breccia," described by Mr. Symonds in the 'Transactions of the Geological Society,' and are associated with numerous spines of fishes.

On the Geology of a Part of Sligo. *By* A. B. Wynne, *F.G.S.*

In this paper the author stated that he had put together a few notes upon an extensive district. They were made during a short tour to the co. Sligo and part of Leitrim, in the summer of 1862; and he alluded to papers by Sir R. Griffith, Archdeacon Verschoyle, and Mr. John Kelly, in the 'Proceedings of the Geological Society,' all of which referred to the country under consideration. He then proceeded to describe the district as composed of a widely spread, nearly horizontal series of stratified rocks, consisting of sandstones below and above, with a thick band of limestones interstratified with other sandstones between. This horizontal group represents the Carboniferous formation, from the Millstone-grit downwards, and probably a part of the underlying Old Red Sandstone; and the thickness of the group is little less than 2000 feet, roughly estimated from the heights of the mountains formed by these rocks. Cutting across the country formed by these horizontal beds is the rugged chain of the Ox Mountains, extending from Mayo into the co. Leitrim. Some of the most picturesque valleys in the district, like that of Lough Gill, are the lateral ones along the flanks of the Ox chain, which, being formed of gneissose, micaceous, and quartzose rocks, have a totally different aspect from the mountains formed of the limestone and other horizontal beds. The serpentine garnet rock and trap-rocks of these older mountains were next alluded to, and it was stated that, although they seemed to occupy fissures running in various opposite directions, their master-joints or divisional planes were nearly parallel. The denudation which exposed the Ox Mountains, and removed the thick series of

Carboniferous rocks which curves round the eastern end of the chain, was alluded to; and the circumstance of the occurrence of beds of sandstone interstratified in the limestone portion of the horizontal group was given as an instance of the splitting up of the Carboniferous formation into alternations of numerous arenaceous and calcareous strata, as observed in the northern parts of the British Isles. The limestone was stated to be traversed by greenstone trap-dykes, and metalliferous mineral deposits were stated to occur at Lurganboy, King's Mountain, &c.

In conclusion, the drift was alluded to, and sea-shells were stated to have been found therein, in one place at a considerable depth, and at a distance of two miles from the sea; and the horns and skulls, &c., of deer and other extinct animals were mentioned as overlying this deposit, or being just within it. The paper was illustrated by drawings of different portions of the country, and a list of the fossils sent for determination to W. H. Baily, F.G.S., was appended.

ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

BOTANY.

On the Ennobling of Roots, with particular reference to the Parsnip.

By JAMES BUCKMAN, *F.L.S., F.G.S., &c.*

The author, in this paper, explained the processes which he had adopted to convert the woody-branched root of the wild parsnip into the smooth, succulent, fusiform root of the esculent parsnip.

The growth of wild seed was commenced in 1847, in prepared garden-ground, and roots carefully selected and transplanted for the next generation, and so on, selecting roots for seeding until the desired form was attained. This new variety of parsnip is now well known to the gardener under the name of the Student Parsnip*. The author concludes that his experiments with parsnips sufficiently show that this esculent, as well as the carrot, beet, turnip, &c., have nowhere in the wild state that large, fleshy, smooth appearance which belongs to their cultivated forms; and hence, that all the varieties of these that we meet with in cultivation must be considered as *derivatives* from original wild forms, attained by *cultivative* processes.

He states that the facility with which new sorts can be induced, and the constancy with which they are maintained, under great diversities of soil, climate, and treatment, are evidences of the derivative or ennobled nature of our crop plants, which are indeed maintained by the very changes to which their aboriginals have been subjected.

Experiments with Seed of Malformed Roots.

By JAMES BUCKMAN, *F.L.S., F.G.S., &c.*

In this paper it was shown, as the result of direct experiment, that seed derived from malformed, *i. e.* misshapen, crop-roots of both turnips and parsnips resulted in even greater deformities than those presented by the parent.

Thus, a much-forked root of parsnip and another of a swede were selected for seeding, the produce of each being sown in plots side by side with that of good roots, the result of which was that in both instances the bad seed produced only about half the weight of the good, and all the examples of roots from the bad seed were misshapen in a most extraordinary manner.

From these experiments the author draws the following conclusions:—

1. That a degenerate progeny will, as a rule, result from the employment of degenerate or badly-grown seed.
2. That, besides ugly, malformed roots, degenerate seed does not produce nearly the weight of crop of good seed under the same circumstances of growth.

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* It gained the first prize at the International Show at the Horticultural Society for 1862.

3. That, by means of selection, we may produce roots that are well shaped and have the capabilities of yielding the best crop.

4. That, by designedly selecting malformed or degenerate roots for seeding, we may produce a seed that will result in a great or greater degeneracy.

The bearings of this subject are of interest, not only in a physiological point of view, but in the more practical one concerned in every-day cultivation; for upon a due observance of the principles involved will depend the stability or permanency of any particular sort; and as sorts are only arrived at as the result of great care (that is, by successful breeding), so care must be taken for their maintenance.

Reply to the Remarks of M. F. Marcet *on the Power of Selection ascribed to the Roots of Plants. By* Dr. DAUBENY, *F.R.S.*

Dr. Daubeny replied to some remarks by M. F. Marcet, published in the 'Bibliothèque Universelle de Genève,' with respect to the power of selection exerted by the roots of plants, as mentioned in a paper read by him before the British Association at the last Meeting held at Manchester.—See vol. xxx. p. 141.

On a Botanical Chart of the Barony of Burren, County Clare. By F. J. FOOT.

This district is composed of the Upper Carboniferous Limestone, and is remarkable as being the habitat of many rare and interesting plants. Certain lines were laid down on the map, representing the limit of the ranges of these plants through the district. Among others, the author enumerated and commented briefly on the following:—*Arabis hirsuta, Arenaria verna, Cerastium arvense, Geranium sanguineum, Rubus saxatilis, Rubia peregrina, Galium pusillum, Galium boreale, Asperula cynanchica, Melampyrum sylvaticum, Orchis pyramidalis*, var. *flore pleno, Thalictrum majus* and *minus, Helianthemum canum, Spiræa filipendula, Dryas octopetala, Sedum rhodiola, Arbutus uva-ursi, Pyrola media, Gentiana verna, Orobanche rubra, Epipactis ovalis* (of Babington), *Potentilla fruticosa, Adiantum capillus Veneris.*

The last-mentioned plant (the beautiful Maiden-hair Fern) occurs in great abundance in several separate stations in Burren. A few years ago it was only recorded as plentiful from the South Isles of Arran, and sparingly from Connemara and Cahirconree Mountain, county Kerry.

On the Inflorescence of Plants. By JOHN GIBBS.

On the Toot-poison of New Zealand. By W. LAUDER LINDSAY, *M.D. and F.R.S. Edinb., F.L.S., &c.*

During a tour through the New Zealand provinces in 1861–1862, the author was struck with the abundant evidences which everywhere presented themselves of the ravages produced among the flocks and herds of the settlers by the *Toot-plant*, one of the most common indigenous shrubs of these islands. In many cases of losses by individual settlers brought under his notice, the amount from this source alone had been from 25 to 75 per cent. In Otago particularly were such losses felt during the height of the gold mania there, from July to December 1861: the traffic between Dunedin and Tuapeka gold-fields required the service of large numbers of bullocks, a great proportion of which were lost by Toot-poisoning. In colonies which as yet, at least, have depended for their prosperity almost solely on pastoral enterprise, such losses form a material barrier to prosperity; and the concurrent testimony of the colonists in every part of New Zealand proves the great desirability of determining the nature of the Toot-poison, the laws of its action on man and the lower animals, and its appropriate antidotes or modes of treatment. With a view to assist in the attainment of these aims, the author had made notes, on the spot, of a large number of instances of the poisonous or fatal action of the plant on man—adults as well as children—and the lower animals, and had brought specimens home for chemical examination. The chief results of his investigations may be thus stated:—

1. The Toot-poison belongs to the class of *Narcotico-irritants*.

a. Its action on man includes the following symptoms:—coma, with or without delirium; sometimes great muscular excitement or convulsions, the details differing in different individuals; during convalescence, loss of memory, with or without vertigo.

b. In cattle and sheep, they include vertigo, stupor, delirium, and convulsions; curious staggerings and gyrations; frantic kicking, and racing or coursing; tremors.

2. The poisonous portion of the plant,

a. To man, is generally the *Seed*, which is contained in a beautiful, dark purple, luscious berry, resembling the blackberry, which clusters closely in rich pendent racemes, and which is most tempting to children; occasionally the young *Shoots* of the plant, as it grows up in spring:

b. To cattle and sheep, in almost all cases, is the young *Shoot*, which is tender and succulent, resembling in appearance and taste the similar state of asparagus.

3. The following *Peculiarities* exist in regard to the action of the Toot-poison:—

a. A predisposition must exist, such predisposition being produced in cattle and sheep by some of the following conditions or circumstances:—The animal is *not habituated* to the use of the plant; it suddenly makes a large meal thereof after long fasting, or long feeding on drier and less palatable materials, or after exhaustion by hard labour or hot, dry weather. From some such cause, the digestive system is deranged, and is susceptible of more serious disorder from the ingestion of food to which the animal is, at the time, unaccustomed. Hence Toot-poisoning frequently occurs in animals which have just been landed from a long and fatiguing sea-voyage during which they have been underfed or starved, to whom the young Toot-shoots present the most juicy, fresh, pleasant diet.

b. On the other hand, the same kinds of animals, *habituated* to the use of the Toot-plant, not only do not suffer at all, but for them it is regarded as quite equal in value to, and as safe as, clover as a pastoral food. It is an equal favourite with cattle and sheep, whether they have been habituated or not.

c. The predisposition in man is probably produced by analogous conditions depressing the tone of his nervous and digestive systems, or directly deranging them. *Children* are affected out of all proportion to *adults*.

d. Adults who have suffered from the poisonous action of Toot under certain circumstances have been exempt from such action under certain others—the same parts of the plant having been used, and apparently in the same way, in both sets of instances. Moreover, the Toot-berries enjoy, both among the Maoris and colonists, an enviable notoriety on account of the agreeable and harmless wine and jellies they are capable of yielding, the former whereof especially has long been greatly prized. The *seeds*, however, in these cases probably do not enter into the composition of the said wine and jellies.

4. The current *Remedies* for Toot-poisoning among the settlers are, in regard to—

a. Cattle and sheep—mainly bleeding, by slashing the ears and tails. Belladonna has been variously tried, and favourably reported on; by others, stimulants are regarded as specifics (carbonate of ammonia, brandy, or a mixture of gin and turpentine, locally known as "Drench"). Whatever be the nature of the remedy, there is no difference of opinion as to the necessity for the promptest treatment, since, at a certain stage of the action of the poison, *all* remedies appear equally inefficacious.

b. In man the nature of the remedy is still more varied, though emetics and stimulants seem the most rational of those usually had recourse to.

5. The *Toot-* or *Tutu*-plant is the *Coriaria ruscifolia*, L. (the *C. sarmentosa*, Forst.). The plant is variously designated by Maoris and settlers in different parts of the New Zealand islands; and this of itself indicates how familiar it is, and how abundantly and widely distributed. The genus *Coriaria* is a small one, and, if not belonging to a subdivision of the natural order *Ochnaceæ*, probably represents a separate order closely allied thereto and to the *Rutaceæ*. The most distinguished botanists, however, are at issue as to its precise place and alliances in the vegetable system. They are in similar dubiety as to the *species* of the genus, and the *varieties* of the species *C. ruscifolia*, L. In New Zealand there appear to be

at least three *Coriarias*, which some botanists regard as mere varieties of *C. ruscifolia*, L., and others consider separate species. The author had made, in July 1862, an examination of all the species of the genus *Coriaria* contained in the Hookerian and Benthamian Collections at Kew, the result whereof was a strong conviction of the necessity for a critical revision of the whole genus, throughout all its species, wherever distributed. The author considers the specific names of the Toot-plant (both *ruscifolia* and *sarmentosa*) objectionable, as not truly applicable or descriptive; and proposes the specific term *C. tutu*—the Maori name of the plant, as more convenient to indicate the *type* of the species, leaving such terms as *ruscifolia*, *thymifolia*, and *sarmentosa* to represent varieties or other species, as a subsequent critical examination of the genus may render necessary or desirable.

In contrast to, and in connexion with the toxic action of *C. ruscifolia*, the author remarked on the better-known poisonous properties of *C. myrtifolia*, familiar as an adulterant of senna, and on those of other species of the genus *Coriaria*. He announced his belief that the whole genus *Coriaria* must be considered endowed with poisonous properties, probably of the narcotico-irritant class, and that, as such (especially in reference to the extent and importance of the economic losses caused by such species as Toot), it is eminently deserving of thorough scientific investigation.

Under this head he pointed out the fact that—

a. While certain animals seem to be themselves exempt from, or insusceptible to the action of the poison, they may, by feeding upon certain species, or certain parts of certain species of *Coriaria*, and assimilating thereby or secreting the contained poison in their tissues, communicate poisonous effects, or become poisons to man or the lower animals, to which they (the animals first mentioned) have become articles of diet. He cited a recent instance in connexion with *C. myrtifolia*, in which several persons, near Toulouse, were poisoned by a dish of snails which had been fattened on its leaves and shoots [*].

b. That Royle in reference to the fruit of *C. Nepalensis*, Peschier of Geneva in regard to *C. myrtifolia*, and other authorities in regard to other species of *Coriaria*, have published instances of their *harmless* or even *beneficial* effects, under certain circumstances, on man or the lower animals. Such conflicting statements would appear to indicate that there are peculiarities in the action of the poisonous principles of all the *Coriarias*, or discrepancies in the records of instances of the said action, which discrepancies or peculiarities demand reconciliation or explanation at the hands of competent scientific experts.

On the Occurrence of Asplenium viride *on an Isolated Travertine Rock among the Black Mountains of Monmouthshire.* *By the* Rev. W. S. SYMONDS.

Mr. Symonds drew attention, at the Meeting of the British Association held at Oxford in June 1860, to the selection of a peculiar geological habitat by some of the rarer British plants. *Asplenium viride* was found in 1862, by Mr. George Roberts, of the Geological Society of London, growing in considerable abundance on an isolated rock of travertine, Capel-le-fin, Llanthony, Monmouthshire. This *Asplenium* is not known elsewhere in the district.

ZOOLOGY.

On the Generative Zooid of Clavatella. *By* Professor ALLMAN, *M.D., F.R.S.*

In this communication the author confirmed the observations of Hincks and Krohn with regard to the generative zooid of *Clavatella prolifera*, Hincks, and stated that he had succeeded in fully demonstrating the gastro-vascular system described as existing in it by Krohn.

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[*] Medical Times and Gazette, Sept. 13, 1862, p. 282.

On an Early Stage in the Development of Comatula.

By Professor Allman, *M.D., F.R.S.*

This paper was also read in Section C, with fuller remarks on the palæontological relations of the subject of it. An abstract is given in the proceedings of that Section (p. 65).

On the Structure of Corymorpha nutans. *By* Professor Allman, *M.D., F.R.S.*

The body of the polype was described as presenting a continuous cavity as far back as the zone of posterior tentacula. From the floor of this cavity a large conical mass of vacuolated endoderm projects forwards, and nearly fills the posterior wider part of the cavity, whose extension backwards seems at first sight not to be continued beyond the zone of posterior tentacula. There is here, however, in reality, no interruption of the general body-cavity; for the axis of the conical projecting mass of endoderm is perforated by a channel, which thus continues the cavity backwards to the summit of the stem.

A system of inosculating longitudinal tubular vacuolæ was described as existing in the stem; they are indicated externally by the longitudinal coloured lines visible even by the naked eye. At the summit of the stem they coalesce and become continuous with the cavity of the body. In these tubes, distinct currents, similar to those so long known in the stem of *Tubularia indivisa*, were occasionally very perceptible under the microscope.

Under a high power of the microscope, delicate parallel longitudinal striæ may be detected, lying externally to the tubular vacuolæ; they are situated between the ectoderm and endoderm, and may be traced upwards on the body of the polype as far at least as the zone of posterior tentacula; they seem to consist of fine tubular fibres, and are apparently the equivalent of the fibres (muscular?) visible beneath the ectoderm of *Clava*, *Coryne*, &c. Still finer circular striæ may also be occasionally witnessed under a high power running transversely round the stem; but the author could not determine whether these represent fibres or mere rugæ in the ectoderm.

The gonophores are medusiform, and were described as belonging to the generic type of *Steenstrupia* (Forbes). They were liberated in abundance from the specimens examined. The generative elements were not visible in any of the medusoids at the time of their liberation; but the author obtained from the same part of the sea where the *Corymorpha* occurred a free *Steenstrupia*, a little larger than the medusoids of the present species at the time when they become detached, and which he did not hesitate to consider as specifically identical with them, and in this the generative elements were quite distinct between the ectoderm and endoderm of the manubrium.

The species of *Corymorpha* which constituted the subject of this communication was considered by the author as identical with *C. nutans* (Sars), though it does not entirely agree with the diagnosis of that species as given by Sars. It was discovered in the Frith of Forth last summer.

On some new British Tubularidæ. *By* Professor Allman, *M.D., F.R.S.*

The author gave the following diagnoses of new species of *Tubularidæ* which he had obtained during the autumn of 1862 on the coasts of Shetland and Devonshire.

Clava diffusa (mihi). Polypes about ⅙ of an inch in height, light rose-colour, developed at intervals upon a creeping reticulated stolon; tentacula about twenty. Gonophores scattered, commencing just behind the posterior tentacula, and thence extending singly, or in small clusters, for some distance backwards upon the body of the polype. In rock-pools at low-water spring-tides. Out Skerries, Shetland Isles.

Tubiclava (mihi, nov. gen.). Polype claviform, supported on the summit of free stems, which rise at intervals from a creeping stolon and are invested by a chitinous periderm; tentacula filiform, scattered. Gonophores, dense clusters of sporosacs aggregated immediately behind the posterior tentacula.

Tubiclava lucerna (mihi). Zoophytes about 2 lines in height; stems quite simple, or rarely with a short lateral branch; periderm clothing the stem corrugated, dilated at the base of the polype: pale yellowish brown. Polype, when extended, about equal to the stem in height; white, with pale ochreous centre; tentacula about twenty, confined to the anterior third of the polype. Creeping over the surface of loose stones in the bottom of a rock-pool, Torquay. On stones between tide-marks, Dublin Bay.

Eudendrium humile (mihi). Zoophyte delicate, rising to about ¾ths of an inch in height, much and irregularly branched; main stems and branches distinctly annulated throughout. Polype yellowish vermilion, vase-shaped, with a circular groove near its base and a trumpet-shaped proboscis; tentacula twenty or twenty-three, with the alternate ones elevated and depressed in extension. Gonophores (male) surrounding the body of the polype, and springing each by a short stalk from the circular groove which passes round the polype near its base, each gonophore consisting of two superimposed chambers. Female gonophores borne both by the base of the polype and by the cœnosarc immediately behind it. Rooted to the bottom of rock-pools near low-water spring-tides, Torquay.

Eudendrium vaginatum (mihi). Zoophyte much branched, rising to about an inch and a quarter in height; main stems and branches deeply and regularly annulated throughout. Polypes vermilion, with about eighteen tentacula, and having the body, as far as the origin of the tentacula, enveloped in a loose, corrugated membranous sheath, which loses itself posteriorly upon the polypary. Gonophores not known. In rock-pools at extreme low-water spring-tides, Shetland.

Perigonimus serpens (mihi). Zoophyte consisting of short, simple, erect stems about 2 lines in height, terminated by the polypes, and rising at short intervals from a creeping stolon, which forms an irregular network upon the surface of other bodies, the whole of the stems and stolon occupied by a reddish-orange cœnosarc, and clothed with a delicate transparent periderm, which does not form a cup-like dilatation at the base of the polypes. Polypes reddish orange, with about twelve or fourteen tentacula, so disposed that in complete extension they are held with alternate tentacula elevated and depressed; body of polype oval, with proboscis conical. Gonophores medusiferous, borne by the creeping stolon, and elevated each upon a rather long peduncle. Medusoids dome-shaped, with the vertical slightly exceeding the transverse diameter. Manubrium reaching to about one-half the depth of the bell, with a simple mouth destitute of tentacula; marginal tentacula two, opposite, very extensile, and with large reddish-orange bulbous bases, without evident ocelli; the intermediate radiating canals terminating each in a very small bulbous dilatation. Growing over the stems of *Plumularia setacea*; dredged from about 12 fathoms, Torbay.

Perigonimus minutus (mihi). Zoophyte very minute, consisting of simple stems rising to the height of about a line and a half from a creeping stolon, and bearing the polypes upon their summit; periderm dilated round the base of the polype. Polypes ash-brown, with seven or eight, rarely twelve tentacula, held irregularly during extension, and with little or no curvature. Gonophores pyriform, medusiferous, borne at various heights upon the stem, and supported on rather long peduncles. Medusoid with the summit suddenly contracted, so as to give a somewhat conical form to the umbrella; two opposite radiating canals terminating each in a pale-brown bulb which is continued into a very extensile filiform tentaculum, the alternate two canals terminating each in a much smaller bulb without tentacle; no evident ocellus; manubrium short, with a four-lobed lip, but without oral tentacula. Forming a fringe round the edge of the operculum of *Turritella communis* dredged in Busta Voe, Shetland. Out of between twenty and thirty specimens of living *Turritellæ* examined, not one was free from this remarkable little zoophyte.

Perigonimus muscus (mihi). Zoophyte consisting of numerous erect stems about ½ an inch in height, not composed of coalesced tubes, springing at intervals from a creeping stolon, and sending off short branches, which are themselves, for the most part, without further ramification; periderm light brown, slightly corrugated, and with a well-marked cup-like dilatation at the base of the polype. Polypes semi-retractile, light reddish brown, with about sixteen tentacula directed in extension alternately backwards and forwards. Gonophores medusiferous, borne upon a rather [illegible] peduncle, and springing from the branches at a short distance behind the polype. Medusoid dome-shaped, with the four radiating canals terminating below each in a large reddish bulb which sends off two very extensile filiform tentacula, having an ocellus at the base of each; manubrium extending to about a third of the entire depth of the umbrella, and with four short oral tentacula. The medusoid is thus, in all points, undistinguishable from that of *Perigonimus ramosus*, Van Beneden. In a rock-pool, Torquay, where it occurred abundantly, creeping over the bottom in small moss-like tufts.

Tubularia bellis (mihi). Basal portion of cœnosarc prostrate, creeping, and sending up short, free, sparingly branched stems, which rise to three-fourths of an inch or one inch in height; periderm, where it covers the lower part of the stems and the whole of the prostrate portion, marked by wide but distinct annulations; cœnosarc orange, deepening in tint towards the base, expanding into a collar immediately below the polypes. Polypes measuring, in full-sized specimens, about 5 lines from tip to tip of the extended tentacula; body of polype scarlet. Gonophores borne upon short erect branched peduncles, each gonophore with four well-marked tentaculoid tubercles on its summit; peduncles and spadix scarlet. A beautiful little zoophyte, conspicuous by the bright colour and large size of its polypes. It occurs attached to the bottom of rock-pools at extreme low-water spring-tides, Shetland.

Observations of the Habits of the Aye-aye living in the Gardens of the Zoological Society, Regent's Park, London. By A. D. BARTLETT.

The subject of the following remarks is a fine adult female of the Aye-aye (*Chiromys madagascariensis*), which arrived in this country on the 12th of August last. On the voyage this animal produced a young one, which lived about ten days. On arriving here she was in poor condition and very feeble; she soon, however, began to feed freely, and has now considerable strength, as is shown by the timber destroyed in the cage in which she is kept.

This animal is much blacker, and appears larger, than the male of this species now in the British Museum; the long hairs on the back of the neck, extending to the lower part of the body, have white points; these white points are thickest above, and become less numerous towards the limbs and tail, which appear quite black; the hairs of the tail, however, are white or grey at the roots (this can only be observed by separating them); the chin and throat are dirty white, which colour extends over the chest; the short hairs on the face are a mixture of dirty grey and white, the long hairs are black; the eye slight brown, surrounded by dark-coloured hairs; the nose and muzzle are of a dirty flesh-colour, the lips pink; the ears shining black and naked, but thickly studded with small protuberances; the feet and toes are sooty black, with the under surface and claws lighter, inclining to flesh-colour. The situation of the mammæ is remarkable: they are two in number, and placed at the lowest part of the abdomen (the animal differing in this respect entirely from the Lemurs and Bats, the teats of which are on the breast).

The Aye-aye sleeps during the day, and the body is then generally curved round and lying on its side; the tail is spread out and flattened over it, so that the head and body of the animal are almost entirely covered by the tail.

It is only at night that the Aye-aye exhibits any activity. I hear her crawling about and gnawing the timber when, to me, all is perfectly dark; and I have been surprised to find that upon the introduction of a light, directed to the face of the animal, she does not exhibit any signs of uneasiness, but stretches out her arm and tries to touch the lamp with her long fingers. She frequently hangs by her hind legs, and in this position cleans and combs out her large tail, using the slender hook-like third finger with great rapidity, reminding one strongly of the movements of the large Bats (*Pteropus*). This skeleton-like finger is used with great address in cleaning her face and picking the corners of the eyes, nose, mouth, ears, and other parts of her body; during these operations the other fingers are frequently partially closed.

In feeding, the left hand only is used, although she has the full use of her right one. The mode of taking her food requires careful attention, in consequence of the very rapid movement of the hand during the process. The fourth finger (which is the longest and largest) is thrust forward into the food, the slender third finger is raised upwards and backwards above the rest, while the first finger or thumb is lowered, so as to be seen below and behind the chin; in this position the hand is drawn backwards and forwards rapidly, the inner side of the fourth finger passing between the lips, the head of the animal being held sideways, thus depositing the food in the mouth at each movement; the tongue, jaws, and lips are kept in full motion all the time. Sometimes the animal will advance towards and lap from the dish like a cat, but this is unusual. I have never heard her utter any cry, or produce any vocal sound, during the many hours at night in which I have watched her habits, nor has she appeared shy or angry at my presence.

With reference to food, this creature exhibits no inclination to take any kind of insects, but feeds freely on a mixture of *milk, honey, eggs,* and any *thick, sweet, glutinous fluid,* rejecting meal-worms, grasshoppers, the larvæ of wasps, and all similar objects. Consequently I am inclined to think that this animal is not insectivorous. Its large and powerful teeth lead me to infer that it may possibly wound trees, and cause them to discharge their juices into the cavity made by its teeth, and that upon this fluid it probably feeds. This appears to me the more likely, as I observe that our specimen returns frequently to the same spot on the tree which she had previously injured. I am also strengthened in my opinion by noticing the little attention paid by the animal to its food. It does not watch or look after it; for I have on several occasions removed the vessel containing its food during the time the animal was feeding, and the creature continued to thrust its hand forward, as before, upon the same spot—though after a while, finding no more food, she discontinued, and moved off to search for more elsewhere. This apparently stupid act is so unlike the habits of an animal intended to capture or feed on living creatures that I am inclined to believe that the Aye-aye feeds upon inanimate substances. I have frequently seen it eat a portion of the bark and wood after taking a quantity of the fluid food.

The excrement of this animal much resembles the dung of small rabbits, being in separate nearly round balls.

On Marriages of Consanguinity. *By* GILBERT W. CHILD, *M.D. Oxon.*

Two opposite views of the effect of the above marriages have been held—

(1.) That they are unnatural, and entail degeneracy upon their offspring as a natural consequence, and independently of the ordinary laws of inheritance.

(2.) That they are not contrary to any law of nature; and that when ill consequences are observed to follow them, they do so by ordinary inheritance only.

Two kinds of evidence have been employed in investigating this subject—

(1.) That derived from observation and statistics in the case of human beings, and

(2.) From carefully recorded experiments in the case of animals.

The former tends somewhat to support the first opinion, and the latter the second.

Upon criticism of the evidence of the former kind, it appears that the results of various observers are inconsistent with one another, and that in one instance a similar investigation has shown worse results to be produced from the intermarriage of natives of different European countries than those alleged to have followed from the marriages of blood-relations. Further, the impossibility of obtaining correct family histories is sufficient to invalidate all evidence of the kind in such cases as the present. On the other hand, the evidence from the breeding of animals is clear and conclusive up to the point that animals are known to have been bred with a degree of closeness physically impossible in the human race, without any apparent degeneracy. This evidence is open to one serious objection, viz. that the animals so bred are subject to careful selection, which is impossible in the case of mankind. This is an objection, in fact, not against consanguineous marriages altogether, but against such marriages between unhealthy persons, and proceeds on the hypothesis that the ordinary laws of inheritance affect close-bred animals equally with others. It is therefore consistent with the second opinion, and inconsistent with the first.

The remainder of the paper was occupied by the relation of several observations upon mankind made in the Mediterranean, the Scottish islands, in Cornwall, and elsewhere by Dr. Davy, and kindly communicated by him to the writer, all of which tend to show that many instances are to be found in which inhabitants of isolated districts, known to intermarry closely, are seen to be in possession of more than average health; also by one case observed by the writer in a race of cats, in which certain peculiarities were found to reappear in the third generation, after at least two successive distinct crosses.

The writer's conclusions are as follows:—

1. That statistical evidence from observation of man is peculiarly inapplicable to questions of the kind under discussion.
2. That the evidence in favour of the opinion that close breeding is contrary to a law of nature is highly unsatisfactory.
3. That there is positive evidence, from the results of recorded observations upon animals, that no such law affects them—*i. e.*, that where the causes of degeneracy are absent, any degree of close breeding may exist without producing ill effects; and therefore,
4. Unless we are prepared to believe in two distinct physiologies, the same must be true of the human race.
5. It will remain an interesting question, how far reasoning similar to the above will be found to affect the views recently put forward by Mr. Darwin, in his work on the fertilization of Orchids.

The following are the works referred to in the paper of which the above is an abstract:—

Devay. Hygiène de Famille, 2nd edit, deuxième partie, sec. ii. ch. iv. v.
Bemiss. In Journal of Psychological Medicine for April 1857.
Child. In Medico-Chirurgical Review for April 1862.
Bondin. In Comptes Rendus for June 16, 1862.
Anderson Smith. In Lancet for July 5, 1862.
Youatt. The Horse, p. 317 (edit. 1855).
Samson. In Comptes Rendus for July 21, 1862.
Beaudouir. In Comptes Rendus for August 5, 1862.
Jourdon. In Comptes Rendus for August 11, 1862.
Stonehenge. (J. H. Walsh.) The Horse, in the Stable and in the Field, p. 139.
Darwin. On the Fertilization of Orchids (*passim*).

On Ribs and Transverse Processes, with special relation to the Theory of the Vertebrate Skeleton. By Dr. CLELAND.

In the first part of this paper, the points were sought to be shown in which prevailing theories were untenable when compared with the phenomena exhibited by ribs and transverse processes in different classes of Vertebrata.

According to the writer of the paper, all morphological discussions resolve themselves into investigations of the relative amount of significance attachable to different classes of phenomena. We compare structures, and inquire in what respects they differ and in what they correspond. The question then arises, what points of difference or correspondence are of primary importance, and what points are only subordinate? The importance of such points can only be estimated by their prevalence in a series of animals, and the time of their appearance in the embryo. Now, looked at in the earliest condition, the embryo is developed from a portion of the germinal membrane split up into layers, which fold inwards to complete the outline of the body in such a manner that the innermost layer forms the epithelial lining of the intestine and appendages, while the outermost layer forms the cuticle, together with the brain and spinal cord. The spinal cord is thus originally superficial, and it only becomes deeply placed in consequence of processes, projected from the middle and superficial layers, rising on each side of it and uniting in the middle line. On the other hand, the visceral cavity is not bounded by processes projected from the opposite aspect of these layers, but by the layers themselves; therefore the visceral ring cannot be appropriately compared to the neural ring, which is formed merely of two radiations given off from the visceral ring. Yet the prevailing theories, according to which the ribs and transverse processes of mammals, birds, reptiles, and fishes are compared, *e. g.* those of Müller and Owen, require us to believe that the skeleton is so planned round the bodies of the vertebræ, that the neural arch on the dorsal aspect corresponds to the visceral arch on the ventral aspect. That condition is only found in the tail; and the tail is not a typical portion of the body, but a degenerated series of segments, in which the products of the deepest parts of the embryo are entirely unrepresented.

With regard to the series of structures traced back into the tail, it was shown that structures lying in series were not necessarily strictly homologous, that, in fact, correspondence was a thing of degree, and that inferior arches of caudal vertebræ were found in series sometimes with mesial spines, sometimes with vessel-embracing arches, sometimes with costal arches of trunk-vertebræ, and sometimes with more than one of these. The key to the comprehension of the skeleton was maintained to lie in the double relation of the skeleton of the trunk to the visceral cavity and chorda dorsalis, both being to it centres, but in different senses—the visceral cavity being that which it tended to encircle, the chorda dorsalis the line from which its efforts to encircle the visceral cavity began.

The correspondence of inferior caudal arches of one class of Vertebrata to those of other classes was shown to be of primary importance; and their differences in respect of attachment, and of the structures with which they were in series, of secondary importance.

All transverse processes or ribs tending to embrace the visceral cavity were shown to have a primary correspondence, even though attached to different parts of the vertebræ, and to be more closely allied one with another than to any structure projecting into the muscles, such as the superior transverse processes and ribs of fishes. (This paper is published in full in the 'Nat. Hist. Review' for Jan. 1863.)

On Geoffroy St.-Hilaire's *Distinction between Catarrhine and Platyrrhine Quadrumana. By* Dr. Collingwood, *Liverpool.*

The terms applied long since by this eminent French naturalist are of great general importance, and point out very characteristic distinctions; but the *definitions* universally given of those terms are such as to make the terms themselves appear liable to numerous exceptions. Thus, the Old-World Monkeys possess nasal septa varying from $\frac{1}{8}$ inch (*Semnopithecus*) to $\frac{1}{2}$ inch in thickness (*Colobus*); while in those of the New World, although the septum is sometimes (*Cebus*) $\frac{3}{4}$ inch thick, in other instances it does not exceed $\frac{1}{8}$ inch (*Eriodes*). Neither do the definitions "nostrils opening beneath (or in front of) the nose," and "nostrils opening to the side of the nose," apply by any means generally. It appears as though the spirit of St.-Hilaire's distinctions were quite forgotten by his successors, who have endeavoured to connect all the Quadrumana under a Procrustean rule. Typical animals fulfil, for the most part, the definitions given; but aberrant genera wander in this respect, as in others, from the ordinary definitions. It is to the *form* of the septum itself, in its anterior aspect, that we must look for the real basis of St.-Hilaire's distinctions—that form being wedge-shaped in the Monkeys of the Old World, and hourglass-shaped in those of the American continent. This causes all the curious changes of direction which the nostrils undergo, and is without exception. Hence it results that in Catarrhine Quadrumana the lower angles of the nostrils rapidly *converge* over the mouth, while those of the Platyrrhine Monkeys *diverge*—a test which, while it is most readily applied and is not liable to misinterpretation, is at the same time altogether independent of the *thickness* of the nasal septum.

On the Change of Form of the Head of Crocodiles; and on the Crocodiles of India and Africa. By Dr. J. E. Gray, *F.R.S.*

The author stated that the Crocodile, when first hatched, has the front of the face short and rounded, even in those that have an elongated beak in the adult state. The nose of the different species lengthens, and gradually assumes the form which is the character of the kind; and it is at this age that the peculiar forms of the different kinds are best examined and compared. After the animal has assumed its adult size, the bones of the head dilate on the side, and the forehead and nose become more swollen. The change of form thus produced is so great, that some naturalists have regarded them as distinct species. This dilatation of the sides and increase in

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thickness of the bones of the head are doubtless for the support of the large teeth which are developed as these animals attain their adult age. The author observed, that this was a good instance, as showing the necessity of studying all kinds of animals in all their stages of growth, and under different circumstances. He stated that no species could be said to have been properly observed until all these circumstances had been examined and noted; and that though the notice of a single individual or state of an animal was useful, it could only be regarded as a sign-post, indicating the existence of an animal which required further study and examination. He then proceeded to speak of the African Crocodile. He observed, that Adanson mentioned three crocodiles as found in the Senegal. Cuvier, in his monograph, thinks that Adanson had made some mistake, and makes some very severe remarks on the inaccuracies of travellers; but more recent researches had shown that in this case the traveller was correct, and the philosopher at fault. Adanson mentions the Green and the Black Crocodiles and the Gavial of Senegal. There can be no doubt, from the West-African specimens which are in the British Museum, that Cuvier was right in regarding the Green Crocodile as the crocodile also found in the rivers in the northern and southern parts of Africa. Cuvier, on the other hand, considered the Black Crocodile of Adanson was identical with the Alligator with bony eyebrows found in South America. This is not the case; for there is a Black Crocodile found in West Africa, which is often imported into Liverpool; and there are specimens in the British and Liverpool Museums, and some young ones living in the Zoological Gardens in the Regent's Park: it is a true crocodile, but peculiar from having three long plates in the eyelids; and it was probably this peculiarity that misled Cuvier. It is to be observed, that the French naturalists have not yet discovered this fact; for the author stated that he had recently purchased from the French Museum the skeleton of this African Black Crocodile under the name of *Alligator palpebrosus* from the Brazils; and there was little doubt that it must have been the examination of the skull of this animal that induced some zoologists to believe that some specimens of alligators had the teeth sometimes fitted into notches in the margin, as in the crocodiles, while in fact they were observing the skull of a true crocodile, and not an alligator. The Gavial of Senegal, of Adanson, is most like the *Crocodilus cataphractus* of Cuvier, which has a long nose like a gavial, but is a crocodile: this animal has been redescribed under various names. Dr. Gray stated that the crocodiles of India had been much misunderstood; some authors said the common crocodile of Africa was found in India, others confused more than one species under the name of *C. palustris*. There are four species found in India: two are confined to the estuaries or the mouths of rivers, where the water is brackish,—as *Crocodilus porosus* or *biporcatus*, which is found on all parts of the coast and also in the islands of Java and Borneo, and even on the north coast of Australia: the other is a new species, confined, as far as we at present know, to the coast of Pondicherry. The latter is only known, from a specimen lately received (French), as *Crocodilus biporcatus*. The other two are confined to the inland rivers; and they are sometimes found high up in the mountains, where the water of the river is frozen. It is to be observed that these river-crocodiles, which have been confounded with the African kinds, are known from them by the short, broad shape of the intermaxillary bone, which is separated from the maxilla by a straight suture, while in the crocodiles of the African rivers the intermaxillary bone is produced behind and between the edge of the maxilla. One species is generally distributed over distant parts of India; the other is confined to Siam, and is probably the animal described by the French missionaries, though the specimen in the British Museum has no crest on the occiput; but the author believes that this may be either an effect of age or an individual peculiarity.

On the Production of similar Medusoids by certain Hydroid Polypes belonging to different Genera. By the Rev. T. Hincks, *B.A.*

The author's object in this paper was to put on record the remarkable fact, which had lately come under his observation, that the Tubularian polypes, *Stauridia producta* (Wright) and *Coryne eximia* (Allman), *produced Medusoids which at the time of detachment were undistinguishable from one another.*

The genus *Stauridia* was nearly allied to *Coryne*, but was distinguished from it by having tentacles dissimilar in character. Its upper tentacles were furnished with globular tips, its lower were filiform and rigid; in *Coryne* all the arms were capitate. The *S. producta* was a small, creeping, unbranched form; the *C. eximia* was branched and attained a considerable size. Yet of the life-series of these two Hydroids, though dissimilar in general character, *one term was identical.* A strictly analogous fact would be the production of flower-buds absolutely identical by two plants of different genera.

Reference was also made to the close similarity, if not perfect agreement, existing between the Medusoid of *Coryne eximia* and that of the *C. Sarsii* of Lovén.

The author then described the gonophores of the *Stauridia producta*, and the development of its Medusoid, which was characterized as having a somewhat bell-shaped umbrella, studded with thread-cells; a rose-coloured *manubrium*, with a simple mouth; four radiating vessels; four tentacles, which originated in as many rose-coloured marginal tubercles, on one side of which was a dark reddish-brown ocellus. The arms were very extensile, set with knot-like clusters of thread-cells, and terminating in a spherical bulb. There were no marginal bodies except the tentacles.

The author objected to the use of the term *Medusoid* to designate the free reproductive body of the *Hydroida*, as tending to perpetuate a false conception of the nature of the sexual zooid. It helped to keep up the idea of its distinct and absolute individuality, and to conceal its real significance as the mere equivalent of the flower-bud in the plant. In the life-series of the Hydroid the polype was the *alimentary zooid*, and the sexual element or term might be conveniently and correctly designated the *gonozooid.*

On a Species of Limopsis, *now living in the British Seas; with Remarks on the Genus. By* J. GWYN JEFFREYS, *F.R.S.**

The author described the animal of *Limopsis aurita* (Brocchi), which he had lately taken by dredging off the north coast of Shetland, and he gave an historical account of the genus. This discovery, in a recent state, of a shell previously known only as a tertiary fossil, was adduced by Mr. Jeffreys in support of an opinion which he had elsewhere expressed, that many species of Mollusca, which were supposed to have become extinct, existed somewhere in the vast extent of the present submarine area. A knowledge of the animal of *Limopsis*, and of the true position of the genus, was among the desiderata of both conchologists and geologists. A list of the recent species, with particulars of their synonymy and habitat, was appended to the paper.

On a Specimen of Astarte compressa *having its Hinge-teeth reversed. By* J. GWYN JEFFREYS, *F.R.S.*

The author exhibited a specimen of *Astarte compressa*, taken by Mr. Robert Dawson in the Moray Frith, having only one primary tooth in the left valve, and two primary teeth in the right valve, being the contrary of what usually occurs. The muscular impressions were in their ordinary position. Mr. Jeffreys considered this to be a case of partial or incomplete reversal, and that it was different from the cases of reversed bivalves which had been noticed by Dr. Gray in the 'Geological Journal' for 1824 and 'Philosophical Transactions' for 1833. In those cases the shell was *inequivalve*; in *Astarte* it is *equivalve.*

Notice of some Objects of Natural History lately obtained from the Bottom of the Atlantic. By Prof. W. KING.

Her Majesty's ship 'Porcupine' has been engaged during a portion of the past summer in taking deep-sea soundings on the west coast of Ireland, in connexion with the proposed Atlantic-telegraph scheme; and the author has been authorized by the Lords Commissioners of the Admiralty to draw up a report on the various organic and inorganic objects obtained during the expedition.

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* See Annals of Natural History, 3rd ser., vol. x. p. 343.

On the present occasion he gave a brief summary of his examinations.

The greatest depth at which specimens have been obtained is 1750 fathoms. e soundings from this and less depths, up to 1000 fathoms, consist almost tirely of microscopic organisms, such as those made known by Bailey, Wallich, d others, and procured by similar expeditions.

The marvellous profusion of Foraminifera and other minute structures in the undings shows that there is forming at the bottom of the Atlantic, wherever it scends below the level of a few hundred fathoms, a wide spread of calcareous posits, which will eventually become converted into beds of limestone. While arly all the particles of these deposits are the shells of dead Foraminifera and eir impalpable débris, it is evident that the surface of the Atlantic bed is one st sheet of the same organisms in a living state, whose office it is to clear the aters of the ocean of the mineral and organic impurities which are ever flowing to them.

Although perforating-shells are living at great depths, Prof. King does not ink there are any grounds for apprehending that they would bore into a telegraph ble; and he is inclined to believe that there is little chance of its getting injured laid down on foraminiferous bottoms, as in such places chemical and vital tions appear to be going on so rapidly and unceasingly, that a cable cannot but ecome covered up in the course of a few years with a considerable deposit of lcareous matter.

The expedition has been fortunate in bringing to light some interesting facts in icroscopic life,—in making known some species of shells and other animals new to e British fauna,—and in extending our knowledge of the habitats of certain rare pecies. A fishing-bank which has been discovered, yielded to the dredge, at 00 fathoms, *Leda pygmæa*, *Pisidium fulvum*, *Arca raridentata*, *Limatula suburiculata*, *Scissurella crispata*, *Crania norvegica*, &c., besides Sponges, Starfishes, nd Sea Urchins. Of fishes, a species of *Rhombus*, allied to the Whiff, and a pecies of *Sebastes*, allied to the Norwegian Haddock, were dredged on the shalower parts of the bank. Specimens of a Pipe-fish were captured on the surface, early 200 miles west of Galway: the fishes appear to be unrecorded as British pecies. The same prolific bank yielded an abundance of a large Hermit Crab, pecimens of which were taken tenanting the rare shell, *Buccinum ovum*. At the epth of 340 fathoms the lead brought up orbulo-globigerinous mud, containing ead specimens of a *Pecten*, an *Arca*, and a *Pectunculus*, all of which appear not o be known as British; also specimens of *Trochus millegranus*. A perfectly fresh pecimen of a new *Cochlodesma* was also brought up from the depth of 1000 athoms, 100 miles west of Cape Clear.

Notes on Sphærularia Bombi. *By* JOHN LUBBOCK, *F.R.S.*

In the first number of the 'Natural History Review' (January 1861), the author has given an account of this curious entozoon, which was first described by Léon Dufour, and very appropriately named by him *Sphærularia Bombi*, the generic name being taken from the "spherules" by which the body is covered, and the specific name indicating the victims which are attacked. It has also been observed by Siebold, who met with the young. At one end, in every single specimen, was attached a small nematoid-like worm, closely resembling a young *Sphærularia* in form and size, and which the author presumed to be the male. So small however was it, so diminutive in comparison with its gigantic mate, that it had escaped the notice both of Léon Dufour and of Von Siebold. It was always attached in the same manner, namely, at a point near the tail, but distant from it by about one-fifth of the whole length of the animal, and was affixed to the female body almost at one extremity and at the end opposite to the opening of the female generative orifice.

The internal organs of *Sphærularia* were stated to consist only of a long, single ovary and a double row of large cells, which were attached at the two ends, but, with that exception, lay freely in the general cavity. No mouth or anus, no intestinal canal, muscles, nerves, or vessels, were found in this curious and abnormal entozoon.

The author now confirms his previous statements. He has also examined a number of Bees in winter, hoping to ascertain the mode of development. But though he has met with specimens in which the female portion was so little developed as to be even smaller than the male, still in every case the organic whole consisted already of these two parts.

The youngest females contained a quantity of brownish granules, which extended from one end of the body to the other. As the animal increased in size, the granules remained stationary, and became more and more compact, so as to form a sort of rod. When the ovary became distinguishable, it was found that this rod, which in the meantime appeared to have undergone little alteration, occupied the lower part or uterus, with its lower end close to the vulva. In the younger females the eggs did not descend in the uterus as far as the "rod;" but in more mature specimens the eggs as they made their way towards the vulva passed along the side of it, without breaking it up or altering its position. If therefore, as seems probable, the "rod" is the seminal element, the impregnation of the eggs is thus simply and thoroughly secured.

The author also gives some account of the development of the spherules and of the large fat-cells.

He expresses his regret that he has not yet been able to trace out the whole development, but it has not been from any want of perseverance on his part. He has examined in the winter months more than one hundred Humble Bees. The young *Sphærularias*, however, are *very* difficult to find, not only on account of their minute size, but because in consistence, colour, and form they so closely resemble the nerves, muscular fibres, and other organs among which they live. He hopes, however, that future researches may be more successful.

On two Aquatic Hymenoptera. By JOHN LUBBOCK, *F.R.S.*

On one of the early days in August, I was looking for larvæ in some water from a pond near my house in Kent, when I was astonished to see a small hymenopterous insect, *swimming in the water by means of its wings.* This was a phenomenon so surprising that at first I could hardly believe my eyes. Of the very large number of Hymenoptera already described, about 3500 occur in Great Britain; yet not one aquatic species is as yet known; while out of the whole immense list of insects not one is yet recorded as using its wings under water. Entomologists might fairly, therefore, require good evidence before they receive as true a statement so opposed to all previous experience. Not only, however, did further examination disclose a second species, belonging to a different genus (which, however, used its hind legs, and not its wings, in swimming), but I was fortunate enough to succeed in exhibiting to the Entomological Society and also to the British Association living specimens of this interesting little insect.

Moreover it is a very remarkable fact that it was again observed within a few days, and yet quite independently, by another entomologist, Mr. Duchess of Stepney, who found a single specimen. It is certainly a curious coincidence that, after remaining so long unnoticed, it should be found by two separate observers within a few days of the same time. Perhaps this may be, in part at least, accounted for by supposing that during this season it has been more common than usual. I forwarded some specimens to Mr. Walker, who at first considered them to belong to *Polynema fuscipes*, but on a more careful examination satisfied himself that they belonged to a different and hitherto undescribed species, which I propose to name *P. natans*.

Although it did not carry any external air-bubbles down with it, still it was able to remain alive under water for about twelve hours. The family to which it belongs pass their early stages as parasites within other animals, and the perfect insect probably enters the water in search of a suitable victim in or on which she may lay her eggs. Nevertheless the essentially aquatic habits of the species are proved by the fact that the male goes under water as readily as the female.

Without the assistance of figures, it would be useless to attempt any description of the separate parts; but I may remark that if this insect had been extinct, however perfect its remains might have been, no entomologist would have doubted that, like its congeners, it was entirely an aërial insect.

The species may be characterized as follows:—*Polynema natans*, n. s.: male, black; emale, black; legs, eight basal segments of antennæ, posterior part of thorax, and eduncle ferruginous.

The second new species is more peculiar, and must form a new genus. It occurred with the first, but was much rarer, only six specimens having been met with, all of which were females. Perhaps the males are not aquatic in their habits. In this ase, however, it was the hind legs which were used for swimming, although they ossessed no fringe or other apparent indication to adapt them to their new function.

On the Influence of Changes in the Conditions of Existence in Modifying Species and Varieties. By the Rev. W. N. Molesworth, *M.A., Rochdale.*

The author of this paper commenced by giving a brief sketch of the main features f Darwin's theory of the origin of species, in order that its salient points might be ept in view by the audience during the reading of the paper. He then proceeded o point out that the theory thus outlined was not a mere wanton attack on beliefs nd feelings which every one was bound to respect, but was intended to supply a cientific desideratum; and that, whether proved or disproved, it was calculated to dvance our knowledge of the sciences to which it related. He wished it, however, learly to be understood that his approval was limited to the theory of the origin f species, and not to the conjectures respecting the origin of organic life which re put forward at the close of the book—conjectures which, he submitted, it was mpossible either to prove or disprove, or even to adduce any facts bearing on them, nd which therefore cannot lead to any scientific results.

After considering some objections which had been made against the Darwinian heory, the author of the paper proceeded as follows:—

And how is it that, with all their differences, they all possess so many characters n common? How is it that the line of demarcation which separates them is often o faintly traced that we lose sight of it altogether? These are the questions which Mr. Darwin raises, and to which he has given an answer, which, whether true or alse, is certainly highly ingenious and original, and supported by a large array of acts. Whether his theory is true or not is a matter on which I express no opinion; ut that a necessity exists for a theory on the subject to which it relates is, I would ubmit, a matter that admits of no doubt.

There is another of Agassiz's objections that seems to me better founded than hat with which I have just been dealing. He says, "The assertion of Darwin, which has crept into the title of his work, is that favoured *races* are preserved, while all his facts go to substantiate the assertion that favoured *individuals* have a etter chance in the struggle for life than others." In this passage Agassiz seems o me to have pointed out the respect in which Darwin's theory is defective and tands in need of further elaboration. I contend that he has not paid sufficient ttention to a very manifest and important principle, which has probably played as arge a part in the origination of species and varieties as either the struggle for xistence or natural selection. I mean the *change* which is continually going on n the *conditions of existence*, and which, by affecting a great number of individuals n the same manner, tend to produce similar modifications in all the beings who re surrounded by them. In employing the term "conditions of existence," I mean o imply the totality of the circumstances by which the organized being is surrounded—the air, the climate, the soil, the vegetation, and the animals which inhabit he same area, including those of its own species. All these are, if we look at the matter rightly, conditions of its existence, inasmuch as all of them exercise a more or less powerful influence on it, causing it to be other than it would be if they were absent or different from what they are. The thing to which I desire to draw articular attention is the change which is always going on in these conditions of xistence, owing to their mutual actions and reactions. For instance, the very onstitution of the atmosphere is to a certain extent altered by every organized eing, as well as by the inorganic matter with which it is continually entering into ew combinations. If any one should suppose that the changes thus produced must be quite inappreciable even though carried on through millions of generations, et him reflect for a moment on the enormous quantity of former constituents of the atmospheric ocean which are now buried in the form of coal and other fossil remains, as well as that far greater mass of animal and vegetable excrement and of other organic matter which is mingled with the inorganic substance of the earth's crust, and is composed in a great measure of ingredients abstracted from the atmosphere.

Look again at the changes produced in the conditions of the existence of each animal by all organized beings inhabiting the same area. Some devour it, others are devoured by it; some become more scarce, others more plentiful; some exercise a beneficial, others an injurious influence on it; but all are in some way changing its conditions of existence, and all are being in their turn changed, as Mr. Darwin has so ably pointed out, by the struggle for existence and the process of natural selection. Again, all of them extract from the soil, directly or indirectly, some of its nutritious constituents, and return them to it in different forms, in different places, and under different chemical combinations. Add to all these other causes of change the action of the being itself in altering its own conditions of existence, and it will at once be evident that, in the course of such long periods of time as we have referred to, striking and marked changes must be produced in the conditions of existence of almost every species.

Hence it follows that if we suppose a group of beings to be at one period of their history in harmony with the conditions of their existence, they must at all subsequent periods be more and more out of harmony with it; and that, on the supposition of the invariability of the species, this discrepancy between the species and its environment must at length become so great that its extinction must become inevitable. It necessarily follows from this, that there must be on the part of the species a constant instinctive, though perhaps unconscious, effort to restore the lost equilibrium, to get rid of the sufferings which will arise from the want of it, and to place itself once more in harmony with its conditions of existence; and the greater the change in the conditions, the more strenuous will this effort be. Some one once remarked to Coleridge, "All things find their level." "No," replied that great man, "all things are finding their level like water in a storm." This saying appears to me to describe, with the happiness of genius, the nature of the incessant movement that is always going on in all parts of the world, and amongst almost all its animal and vegetable inhabitants. All are unconsciously striving to keep themselves in harmony with a medium which is continually changing.

In order, then, that they may not be utterly distanced by the ever-changing conditions of their existence so as in time to become extinct, they must possess a capacity for variation in the direction of those changes which is absolutely illimitable, provided only that sufficient time be allowed for its development. That they do possess such a capacity to a certain extent has been triumphantly demonstrated by Darwin. The real question is, Are there any, and, if so, what, limits to this capacity of variation in the direction of actual or possible changes in the conditions of existence? Now, in reference to this question, it seems to me that Mr. Darwin has not sufficiently distinguished between a capacity for variation and a tendency to vary, which, I would submit, are two very different things. I would respectfully contend that the capacity for variation is in the being; but the tendency to vary arises out of the changes which take place in the conditions of existence, and in the efforts unconsciously made by the being to overtake those changes. When, therefore, a species of animals inhabit the same area, they will, generally speaking, be exposed to nearly the same changes in the conditions of their existence. This will almost necessarily lead to similar variations manifesting themselves in the same individuals at the same time, because they will all be exposed to the same changes, and variations thus produced are much more likely to be strengthened and perpetuated than varieties arising from temporary causes, or such as affect individuals only. Mr. Darwin says, "When a variation is of the slightest use to a being, we cannot tell how much of it to attribute to the accumulative action of natural selection, and how much to the conditions of life;" and a little further on, "Such considerations as these incline me to lay very little weight on the direct action of the conditions of life. Indirectly, as already remarked, they seem to play an important part in affecting the reproductive system; and in thus inducing variability and natural selection, will then accumulate all profitable variations, however slight, until they become plainly developed and appreciable by us."

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Now in these passages, and in every other part of his work in which he touches on the subject, Mr. Darwin appears to me to overlook, or at least not to make sufficient allowance for, the progressive changes which are always taking place in the conditions of existence of almost every living creature, although his book teems with proofs of it. But there is another oversight running through the work, and strongly exhibited in the passages just cited. Mr. Darwin speaks of natural selection as *accumulating* profitable variations, whereas it is quite evident that, at utmost, it can only *repeat* them. Natural selection acts, as Mr. Darwin shows, by preserving the serviceable variations, and discarding the unserviceable or injurious; but as it does not produce them, so neither of itself can it strengthen them: that, I maintain, is done by the conditions of existence acting on the variability of the animals which are placed among them. Mr. Darwin elsewhere writes:—"Seedlings from the same fruit, and young from the same litter, sometimes considerably differ from each other, though both the young and the parents, as Müller has remarked, have apparently been exposed to exactly the same conditions of life; and this shows how unimportant the direct effects of the conditions of life are in comparison with the laws of reproduction and of growth and of inheritance; for had the conditions been direct, if any of the young had varied, probably all would have varied in the same manner." I deny this probability. If Mr. Darwin has certainly established anything, it is this, that animals do possess a capacity for variation in almost every direction. But it is equally certain that this capacity for variation differs very much in different individuals, so that the same influences do not produce the same effects, though they tend to do so. And therefore even if we assume (which I am not prepared to admit) that the conditions of life are the same for seedlings of the same fruit, and young of the same litter during the period of gestation, still it would not follow that they were either absolutely or comparatively unimportant, or that the variations which showed themselves were not due to them. In a word, I contend that the capacity for variation is in the animal, but that it depends in a great measure for its development on that assemblage of circumstances which we denominate the conditions of its existence; and the changes, which in the greater part of animals are slowly taking place in those conditions, impress on the variations a certain definite direction, while natural selection tends to the preservation of the most favourable of the variations thus produced. At the same time I am by no means prepared to deny the influence which Mr. Darwin attributes to the laws of reproduction and growth: all I maintain is that he underrates the influence of the conditions of life, and overlooks that of the changes which are slowly but continually taking place in them, at least for most organized beings; and he further employs language which seems to imply that natural selection has something to do with the *production* of favourable varieties, when all his arguments go to prove that it tends only to the preservation of those which have been produced by other causes. I maintain therefore that two classes of inquiries ought simultaneously to be carried on—one into the variability of organized beings, and another into the variations of the conditions of their existence.

After illustrating these views at some length, the author of the paper concluded as follows:—

This is not the place for entering on the theological aspects of the question. Indeed, I am forbidden, I believe, by the rules of the Association to do so. So far from regretting this prohibition, I cordially approve it, regarding it not merely as a regulation of wise expediency, but as the embodiment of a sound principle. I maintain that the intrusion of Scriptural arguments into scientific investigations is as theologically erroneous as it is scientifically mischievous. Let us push our investigations of the Creator's works as far as we can in every direction, without the slightest fear that scientific truth can ever clash with moral and religious truth; and let us apply to the theory before us what Galileo said of his when exposed to objections similar in principle to those which had been urged against Mr. Darwin's, "Quin ipsa philosophia talibus e disputationibus non nisi beneficium recepit. Nam si vera proponit homo ingeniosus veritatisque amans nova ad eam accessio fiet; sin falsa, refutatione eorum priores tanto magis stabilientur."

On the Characters of the Aye-aye, as a test of the Lamarckian and Darwinian Hypothesis of the Transmutation and Origin of Species. By Professor R. Owen, *M.D., F.R.S., F.G.S.*

The author, referring to the results of a recent dissection of the *Chiromys madagascariensis*, Cuv., said, that most naturalists who had had the opportunity of studying the living habits of the Aye-aye in its native climate, from Sonnerat to Sandwith, had observed its faculty of detecting larvæ boring in wood, of gnawing down to their tunnels, and extracting them for food, for which this animal shows a predilection; they also describe the animal as sleeping during the heat and glare of the tropical day, and moving about chiefly by night. Many particulars of the structure of *Chiromys* closely accord with these alleged habits and natural diet. The wide openings of the eyelids, the large cornea and expansile iris, the subglobular lens and tapetum, were, the author remarked, arrangements for admitting to the retina and absorbing the utmost amount of the light which may pervade the forests frequented by the Aye-aye at sunset, dawn, or moonlight. Thus the Aye-aye is able to guide itself among the branches in quest of its hidden food. To discern this, however, another sense had need to be developed to great perfection. The large ears are directed to catch and concentrate, and the large acoustic nerve and its ministering "flocculus" seem designed to appreciate any feeble vibration that might reach the tympanum from the recess in the hard timber through which the wood-boring larva may be tunnelling its way by repeated scoopings and scrapings of its hard mandibles. The Aye-aye was a quadrumanous quadruped, in which the front teeth, by their number, size, shape, implantation, and provision for perpetual renovation of substance, are especially fitted to enable their possessor to gnaw down, with gouge-like scoops, to the very spot where the ear indicates the grub to be at work. The instincts of the insect, however, warn it to withdraw from the part of the burrow that may be thus exposed. Had the Aye-aye possessed no other instrument, were no other part of its frame specially modified to meet this exigency, it must have proceeded to apply the incisive chisels in order to lay bare the whole of the larval tunnel, to the extent at least which would leave no further room for the retracted grub's retreat. Such labour would, however, be too much for the reproductive power of even its strong-built, wide-based, deep-planted, pulp-retaining incisors; in most instances we may well conceive such labour of exposure to be disproportionate to the morsel so obtained. Another part of the frame of the Aye-aye is, accordingly, modified in a singular and, as it seems, anomalous way, to meet this exigency. We may suppose that the larva retracts its head so far from the opening gnawed into its burrow as to be out of reach of the lips, teeth, or tongue of the Aye-aye. One finger, however, the medius, on each hand of that animal has been ordained to grow in length, but not in thickness, with the other digits; it remains slender as a probe, and is provided at the end with a tactile pad and a hook-like claw. By the doubtless rapid insertion and delicate application of this digit, the grub is felt, seized, and drawn out. For this delicate manœuvre the Aye-aye needs a free command of its upper or fore limbs; and to give it that power, one of the digits of the hind foot is so modified and directed that it can be applied, thumb-wise, to the other toes, and the foot is made a prehensile hand. Hereby the body is steadied by the firm grasp of these hinder hands during all the operations of the head, jaws, teeth, and fore paws, required for the discovery and capture of the common and favourite food of the nocturnal animal.

Thus we have not only obvious, direct, and perfect adaptations of particular mechanical instruments to particular functions—of feet to grasp, of teeth to erode, of a digit to feel and to extract,—but we discern a correlation of these several modifications with each other, and with modifications of the nervous system and sense-organs—of eyes to catch the least glimmer of light, and of ears to detect the feeblest grating of sound,—the whole determining a compound mechanism to the perfect performance of a particular kind of work.

But all this must have a cause; and we are led to a conception of the nature of such cause by the analogy of its effect with that of the exercise of faculties that energize in our own intellectual nature—ours, too, the highest that we have direct and material cognizance of in this sphere of life and labour—in which, with such faculties to foresee, invent, and adapt, we dimly conceive, in analogous but more perfect results, the exercise of like faculties in a transcendentally higher degree.

To conceive the direct formation and adjustment of such an organization as that of the *Chiromys* to its purpose accords best with the mode of our finite human adaptive operations, but least with the sum of present observations bearing upon the origin of species. Such observations have led to the conception that the species of organisms may be due to natural laws or secondary causes, operating to produce them in orderly succession and progression*; and also to the suggestion of the mode of operation of such secondary causes†.

As a test of the value of some of these suggestions in making known or rendering intelligible the origin of a species, the organization of the Aye-aye lends itself with peculiar force.

Buffon, assuming that a certain number of species had been originally created after a manner analogous to, and conceivable by, the way in which human machines are made, conceived that there was a tendency in their offspring to degenerate from the original type; and he refers the Linnean species, about 200 in number, which are described in his great work, to about fifteen primitive stocks. As, however, the Aye-aye, had he known as much as is now known of it, might have been referred to a "primitive type or stock," or to one of the "isolated forms" such as Buffon conceived the Elephant and the Mole to be, the author proceeded to apply the Aye-aye, as a test, to Lamarck's hypothesis of the origin of species.

The 'Philosophie Zoologique' teaches that species, like varieties, have their origin, maturity, and departure, changing with the course of the changing operation of the causes that produced them; that such so-induced charges of form and structure lead to changes in powers and actions, and that such actions become another cause of altered structure; that the more frequent employment of certain parts or organs leads to a proportional increase in the development of such parts; and that as the increased exercise of one part is usually accompanied by a corresponding disuse of another part, this very disuse, by inducing a proportional degree of atrophy, becomes another element in the progressive mutation of organic forms‡.

According to the modifying influences suggested by Lamarck, a Lemurine quadruped, attracted by the noise of a boring caterpillar in the bough on which it happened to be perched, instinctively applied its incisors to the bark, and, by frequent repetition of such efforts, increased the mass of the gnawing muscles, which, stimulating the growth of the bone, led to concomitant modifications in the size and proportion of the jaws. The incisors, by repeated pressure, either became welded into a single pair above and below—or, the stimulus to excessive growth being concentrated on one incisor, the neighbouring teeth became atrophied by disuse, and by derivation of their nutrient fluid to the contiguous pulp; hence the preponderating size of the pair of front teeth, and the extent of edentulous space behind them. Concomitantly with the efforts excited by the particular larvivorous tendency of a certain Madagascar Lemur to expose the canal in which its favourite morsel lay hidden, were repeated endeavours to poke the longest finger into the burrow so laid open. The repeated squeezing of the soft skin, with the compression of the nerves and vessels, permanently affected the growth of such digit, and kept it reduced to the blighted state, whereby it happens to be suited to the work of extracting the larva. Lamarck supposes all these changes to be gradual, and effected only through long succession of generations; he assumes that changes of structure, due to habitual efforts and actions, are transmissible to offspring; and he finally invokes, like his successors, the requisite lapse of time and long course of generations. It is to be supposed that, until the modifications of dental and digital structures were brought about, the grub-hunting Lemur subsisted on the necessary proportion of fruits and other food more readily obtainable under the ordinary Lemurine condition. That the same finger should be the seat of the wasting influences on both hands and in all Aye-ayes strikes one as a result hardly to be looked for on the hypothesis of the cause of such specific structures propounded by Lamarck: that there should be a peculiar modification of the muscles of the forearm, whereby both *flexor sublimis* and *flexor profundus* combine their action upon the same tendon, pulling the probe-like digit, is left unaccounted for. The physiologist finds still more difficulty in accepting the explanation of the way in which the peculiar size, shape, and law of growth of the incisors could be brought about. The action of muscles pressing upon the bony sockets might affect the growth of teeth filling such sockets, but could not change a tooth of limited growth, like the incisors of an ordinary Lemur, into a tooth of uninterrupted growth. Besides, the crowns of both the scalpriform incisors of the *Chiromys* and the ordinary small incisors of other Lemurines are formed according to their specific shape and size, before they protrude from the gum: they acquire so much development while the animal still derives its sustenance from the mother's milk. In the Aye-aye the chisel or gouge is prepared prior to the action of the forces by which it is to be worked. The great scalpriform front teeth thus appear to be structures fore-ordained—to be predetermined characters of the grub-extracting Lemur; and one can as little conceive the development of these teeth to be the result of external stimulus or effort, as the development of the tail, or as the atrophy of the digitus *medius* of both hands. The author had elsewhere tested the Lamarckian hypothesis of transmutation by the phenomena of the dentition of the male Gorilla, and no refutation of his argument had appeared.

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* Owen, 'On the Nature of Limbs,' 8vo, 1849, p. 86.

† De Maillet, 'Telliamed, ou Entretiens d'un Philosophe Indien avec un Missionnaire François,' 8vo, 1755. Buffon, Histoire Naturelle, 4to, tom. xiv., "Dégénération des Animaux," p. 311, 1785. Lamarck, Philosophie Zoologique, 8vo, 1809. Vestiges of Creation, 8vo, 1846. Wallace, "On the Tendency of Varieties to depart indefinitely from the Original Type," Proc. Linn. Soc. 1858. Darwin, 'On the Origin of Species,' &c. 8vo, 1859.

‡ Lamarck, *op. cit.* tom. i. chap. iii. vi. vii.

There remained then to be seen whether the subsequently propounded hypothesis of "natural selection" would afford a better or more intelligible view of the origin of the species called *Chiromys madagascariensis*. Applying to the Aye-aye the illustration of his hypothesis, as submitted by Mr. Darwin to the Linnean Society*, it may be admitted that the organization of a Lemur, feeding chiefly on fruits and birds, but sometimes on grubs, is or might become slightly plastic, in the sense of being subject to slight congenital variations of structure. We may also suppose changes to be in progress in the woods of Madagascar causing the number of birds to decrease, and the number of insects to increase, especially of those the larvæ of which are xylophagous. The effect of this might be that the Lemur would be driven to try to catch more grubs. His organization being slightly plastic, those individuals with the best hearing, the largest front incisors, and the slenderest middle digit, let the difference be ever so small, would be to that extent favoured, would tend to live longer, and to survive during that time of the year when birds or fruits were scarcest; they would also rear more young, which would tend to inherit these slight peculiarities. Were the Lemurs to be reduced to this insect-food, those individuals less plastic than the incipient Aye-aye, or not varying in the same way, would become extinct. Acceptors of the hypothesis of "natural selection" may entertain no more doubt that such causes in a thousand generations would produce a marked effect upon the Lemurine dentition and limbs, adapting the form and structure of the Quadrumane to the catching of wood-boring grubs instead of birds, than that any domesticated quadruped can be improved by selection and careful breeding. But, to the author of the present communication, the propounding of such plastic possibilities left no sense of any knowledge worth holding as to the origin of the species called *Chiromys madagascariensis*, no help to the conception of such origin which was at all worth so wide a departure from actual experienced facts. He knew of no changes in progress in the Island of Madagascar necessitating a special quest of wood-boring larvæ by small quadrupeds of the Lemurine or Sciurine types of organization. Birds, fruits, and insects abounded there in their ordinary proportions; and the different forms of *Lemuridæ* there coexisted, with their several minor modifications, zoologically expressed by the generic terms *Lichanotus*, *Propithecus*, *Chirogaleus*, *Lemur*, and *Chiromys*.

On the Zoological Significance of the Cerebral and Pedial Characters of Man.

By Professor R. Owen, *M.D., F.R.S., F.G.S.*

Professor Owen, in illustration of the above characters, exhibited the casts of

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[*] Proceedings, 1858, p. 49.

the brain of a male European and Negro, and a cast of the interior of the cranial cavity of a full-grown male Gorilla; also figures of the bones of the feet of the Man and male Gorilla, in plates from his "Memoir on the Osteology of the Gorilla" (Trans. Zool. Soc. vol. v. pl. 11).

The brain of the Gorilla, as exemplified by such cast, is of a narrow-ovate form, with the small end forward; the cerebrum does not extend beyond the cerebellum; viewed with the lower surface of the medulla oblongata horizontal, it does not extend so far back as the cerebellum does. The difference of size between it and a small-sized Negro's brain was exemplified in the subjoined admeasurements:—

	Gorilla.		Negro.	
	in.	lines.	in.	lines.
Length of cerebrum	4	10	6	3
Breadth of cerebrum	3	9	4	10
Depth (greatest vertical diameter)	2	6½	4	6
Breadth of cerebellum	3	4	3	7
Length of cerebellum	1	10	2	3
Depth of cerebellum	1	4	1	8

In these admeasurements some deduction from the Gorilla's brain must be made for the thickness of the dura mater and other membranes included in the cast: that of the Negro's brain showed it stript of its membranes; and the admeasurements are from a subject corresponding with the smallest of those figured by Tiedemann in the 'Philosophical Transactions' for 1836, pl. 32, in which the posterior cerebral lobes extend half an inch beyond the cerebellum.

Although in most cases the Negro's brain is less than that of the European, Tiedemann and the author of the present paper had observed individuals of the Negro race in whom the brain was as large as the average one of the Caucasian; and the author concurred with the great physiologist of Heidelberg in connecting with such cerebral development the fact that there had been no province of intellectual activity in which individuals of the pure Negro race had not distinguished themselves. The contrast between the brains of the Negro and Gorilla, in regard to size, was still greater in respect of the proportional size of the brain to the body—the weight of a full-grown male Gorilla being one-third more than that of an average-sized Negro.

Passing from this contrast to a comparison of the Gorilla's brain with that of other *Quadrumana*, the author insisted upon the importance and significance of the much greater difference between the highest ape and lowest man, than existed between any two genera of *Quadrumana* in this respect; the brain of the Gorilla, in the contraction of the anterior lobes, in the non-development of posterior lobes extending beyond the cerebellum, and in the paucity, symmetry, and relative size of the cerebral convolutions, so far as they were indicated in the cast, closely accorded with the brain of the Chimpanzee. From these to the Lemurs the difference of cerebral development shown in any step of the descensive series was insignificant compared with the great and abrupt rise in cerebral development met with in comparing the brain of the Gorilla with that of the lowest of the human races. This difference paralleled the difference in the structure of the lower limbs, especially the foot, in the Gorilla and Man; on which difference, as exemplified in the Chimpanzee and lower apes and monkeys, Cuvier had founded the ordinal grade to which he had assigned the genus *Homo*, under the term *Bimana*. The disposition of the hallux as a hinder thumb, with the concomitant modifications of the tarsal bones, was as strongly marked in the Gorilla as in any lower Quadrumane, and the contrast between the foot-structures of the Gorilla and Negro was as great.

The homologies of the parts in the structure of both brain and foot of the Human and Simial Mammalia being demonstrated, as by Tiedemann* and Cuvier†, no hypothesis of the cause of these homologies, with their structural gradations and differences, would abrogate the necessity of the zoological disposition of the different members of the animal kingdom in groups of different degrees of value. The modification of the human foot having been, in the author's opinion, rightly estimated by Cuvier as of ordinal value, he contended that the equal or correlative degree of difference shown in the development of the human brain, regard being had to the higher importance of that organ in the animal frame, necessitated its higher appreciation as a zoological character, and that the now known characters of the Gorilla's brain confirmed the reference of the Bimanous order to the subclass *Archencephala*.

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* "Scrobiculus parvus loco cornu posterioris." (Icones Cerebri Simiarum, fol. p. 14, fig. iii. 2.)

† "Pouce libre et opposable au lieu du grand orteil." "L'homme est le seul animal vraiment *bimane* et *bipède*." (Règne Animal, i. p. 70.) "Pedes hippocampi minores vel ungues, vel calcaria avis, quæ a posteriore corporis callosi tanquam processus duo

On the Homologies of the Bones of the Head of the Polypterus niloticus.

By Professor R. Owen, *M.D., F.R.S., F.G.S.*

Preparations and sections of the skull of the *Polypterus* were exhibited, showing the way and proportions in which the bones of the exo- and endo-skeleton were blended together, more especially the extension of the epencephalic segment backward freely beneath the overarching roof of dermal bones, from which the super-, ex-, and par-occipitals were distinct. Professor Owen referred to a paragraph in his 'Lectures on Comparative Anatomy' (vol. ii. p. 136), in reference to the inconstancy of the dermo-cranial bones of the Sturgeon, and the confusion caused by applying to them the names "super-occipital," "par-occipital," or other synonyms of the vertebral elements of the skull. The same remark applies to *Polypterus*, *Lepidosteus*, and many extinct *Ganoidei*.

On Zoological Provinces. By Sir J. Richardson, *F.R.S.*

This paper consisted mainly of a single question, "What is a zoological province?" A right and full answer would, in the author's opinion, open one avenue to the solution of the origin of species which has occupied the naturalists of this country for several years.

He referred to the Palmipede group of birds. The highest latitudes of the Arctic regions to which man has penetrated are the native places of the Snow Goose, and of various other members of the family, who, having reared their young in two brief months, speed to the southward and winter on the verge of the tropics. Is this whole space, little less in extent than a hemisphere, to be accounted a zoological district?

The range of the Whale is not far short; but land-animals have a much less wide distribution. Has every class of the Vertebrata a different zoological province? and how far are any of them conterminous with the provinces marked out by botanists?

On certain Modifications in the Structures of Diving Animals.

By Prof. Rolleston, *M.D., F.R.S.*

In the class Mammalia, the Cetacea were contrasted with the Phocidæ, and in the class Aves, the Colymbidæ were contrasted with the Cinclidæ, as to the degree of modification which their tegumentary, circulatory, and osseous systems had undergone in adaptation to their aquatic habits.

The skin of the Seal was less specially modified than that of the Whale, and the aberrations from the ordinary Mammalian character which its bones and teeth presented were in like manner less marked than those of the animals with which it was compared. The teeth in the order Seals were often irregular as regarded their number, their implantation, and their permanence in the jaw; and the epiphyses of the vertebræ were often slow to unite with the bodies. All these particularities were instances of correlation of growth existing between the skin and

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medullares proficiscuntur, inque fundo cornu posterioris plicas graciles et retroflexas formant, in cerebro Simiarum desunt; nec in cerebro aliorum a me examinatorum mammalium occurrunt; Homini ergo proprii sunt." (Ib. p. 51.) Both the above propositions are susceptible of flat contradiction on homological grounds, and are, nevertheless, true as zoological characters.

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systems as far removed from its direct influence as the osseous and dental; and all these particularities, together with those of the systems with which they were correlated, were much more marked in the Whales than in the Seals.

The Seals were well provided with intrahepatic venous sinuses, but their reservoirs for arterial blood were far inferior in grade of development to those of the Cetacea. Little could be said as to difference in the degree of patency in the foramen ovale and ductus venosus in the two subjects of comparison, at least so far as the Common Seal (*Phoca vitulina*) and Common Porpess (*Phocæna communis*) might serve as representatives of the two orders. To the rudiments of the fœtal vena umbilicalis and ductus Botalli, in both, the same remark applied.

The stunted salivary glands of the Seals seemed an approximation to the condition of total absence which we find in carnivorous Cetacea; and, but that some of the latter class possessed olfactory bulbs, a similar relation might be said to prevail between these organs also in the two orders.

In both classes alike, the weight of the brain was high as compared with that of the body: in a young *Phoca vitulina* Dr. Rolleston had found it to be as 1 : 46; in a young *Phocæna communis*, as 1 : 60.

The bark of the Seal spoke plainly enough to its want of any such arrangement of the larynx as the Whales possess; but a recent inspection of a large Seal (*Pelagius monachus*) had shown it to possess an exceedingly strong sphincter muscle guarding the entrance to the respiratory passages, and it might be conjectured that the membrano-muscular pouch in connexion with the nasal passages in the *Stemmatopus cristatus* was a foreshadowing of the sac so often described in connexion with the Cetacean blow-hole.

Several fœtal structures were permanently retained in the Cetacea. The thymus, as shown by Mr. Turner (Edin. Phil. Trans. xxii. pt. 2), was one of these; certain other remnants of the general formative mass of blastema which surrounds the aorta in the fœtus, noticed by himself in the 'Natural History Review' for Oct. 1861, furnished a second example; and to these the author would now add a third, in the largest remnant of a Wolffian body, or organ of Giraldès, which he had met with in the class Mammalia. The author proceeded to say that, in the two classes of birds which he had to contrast, scarcely any such approximations could be traced between the two sets of structures to be compared.

The modifications in the tibiæ of the birds commonly known as "divers" (*Colymbinæ*), and the large intrahepatic venous sinuses which they, in common with the mammals just spoken of, possessed, were beautiful adaptations to the special habits of these animals; but nothing at all reminding us of these structures would be found in such a bird as the Water-Ouzel (*Cinclus aquaticus*). Indeed, the soft parts of this bird presented very few points of difference from those of a Redwing (*Turdus iliacus*) dissected at the same time with it, except in the much greater development of the second pectoral muscle. The large size of this muscle was permanently recorded on the keel of the Ouzel's sternum; and this point might perhaps have enabled us, *à priori*, to predict that the bird possessed the peculiar habits which have given it its trivial name. This ridge extends the whole length of the keel in the Water-Ouzel; and in this point, as well as in the lesser relative depth of that process, and in the greater relative breadth of the lateral portions of the sternum, and in its more nearly circumscribed posterior emarginations, the bird in question differed from allied species of dissimilar habits.

Recent Experiments on Heterogenesis, or Spontaneous Generation.

By JAMES SAMUELSON.

The author communicated the results derived from the simultaneous exposure of various kinds of infusions prepared by him in Hull, Paris, and Liverpool. Amongst these results the following afford fresh evidence against the theory of spontaneous generation, and tend to prove the existence of innumerable germs of life in the atmosphere.

Dr. Balbiani (the author's coadjutor in Paris) found certain well-defined species of Infusoria in his infusions, which he also discovered in the moistened dust from his window; and another well-marked species, found in large numbers by Dr. Balbiani in his infusions in Paris, was traced by Mr. Samuelson, first in moistened dust from the high road near Liverpool, then in dust taken from his own window and washed in distilled water, and lastly even in pure, boiled, distilled water, after it had been exposed a few days in the open air in Liverpool. The author watched and carefully described the development of this species (*Cercomonas acuminata*) from its first appearance to its full growth.

PHYSIOLOGY.

On the Function of the Auricular Appendix of the Heart.

By ISAAC ASHE, *A.B., M.B.*

The author considered that the well-marked contrivance exhibited in the appendix, such as the presence of carneæ columnæ in this portion only of the auricle, indicated that it subserved some function more important than that usually assigned to it, namely the better mixing up of the blood received from the veins. Three ascertained facts, none of them of much apparent value separately, would, when connected together, give a hint as to what that function might be.

The first was that the auricle, though having walls much thinner and weaker than those of the ventricle, was yet able powerfully to distend the latter.

The second fact was that the auricle, unlike the ventricle, did not completely empty itself of blood.

The third fact was that the auricular appendix, though placed at a distance from the auriculo-ventricular orifice, yet was the last portion of the auricle to contract.

From these three facts, taken together, Dr. Ashe inferred that the function of the appendix was to effect the complete distension of the ventricle, notwithstanding the powerful resistance of its thick muscular walls when distended nearly to the utmost. The force of the appendix would be transmitted to the ventricle by means of the small column of fluid still remaining in the auricle, and this force would be multiplied within the ventricle as many times as the superficies of the fluid within that chamber exceeded the surface which would be presented by the superficies of the fluid within the appendix. Against the walls of the auricular sinus this force would be a minimum, in consequence of the small superficies of the fluid still remaining within it.

To a certain extent the same thing would be effected by the contraction of the sinus alone, for its force would become multiplied within the ventricle in measure as the superficies of the fluid in the latter increased in proportion to that in the former, which diminished *pari passu*; but the force exerted by the sinus became diminished towards the close of its contraction, just when the maximum effort is required, and would even vanish altogether were it not for the small column of fluid remaining in the auricle. Dr. Ashe regarded the function of the carneæ columnæ as being neither to increase nor to diminish the strength of the appendix, for either object could be attained with smooth walls—yet both views had been put forward —but as being to effect the complete emptying of the appendix, since the force of this organ could not be exerted on the ventricle except by the injection of a considerable quantity of fluid within it. For this contrivance Dr. Ashe suggested the name of "the hydrodynamic apparatus of the heart."

Dr. Ashe also considered that this powerful distension of the walls of the ventricles might be an operating cause of their contraction, analogous to the view which had been suggested regarding the cause of the contraction of the walls of the uterus at the completion of the period of pregnancy.

On the Function of the Oblique Muscles of the Eye.

By ISAAC ASHE, *A.B., M.B.*

The author doubted the view that assigned to these muscles the function of rotating the eyeball on its antero-posterior axis, never having observed such rotation either incidentally or in experiment. The vision might be directed to any object by the action of the recti alone.

The view had been put forward that such rotation was necessary in order that corresponding points of the two retinæ might continue on the same level when the head was inclined to either side. Dr. Ashe considered that this effect could only be produced with reference to a single pair of points in the retinæ at any one moment, and that only at the expense of an increased alteration in the level of every other pair of corresponding points. But he considered the attainment of this object unnecessary, inasmuch as any corresponding pair of points changed their level only with reference to the level of the earth's surface, and not with reference to the point looked at; this point, therefore, with the two on the retinæ, would remain in the same relative position notwithstanding the rotation of the plane containing them. Hence Dr. Ashe considered that the function of these muscles was yet to be assigned; while, on the other hand, a known function existed, capable of being voluntarily discharged, for the exercise of which no voluntary muscle had been assigned, namely, the adjustment of the focal distance of the eye. It had been considered that the ciliary muscle effected this by compressing the globe. No doubt the action of the ciliary muscle might cause short-sightedness, and this defect had recently been remedied by its division; but the ciliary muscle consisted of unstriped fibres, and its action must therefore be involuntary, which was also demonstrated by the fact that the power of voluntary adjustment of the focal distance was not destroyed by its division. Dr. Ashe considered that the position of the obliqui was such that, acting *together*, and not separately as generally supposed, they would compress the globe of the eye, as the ciliary muscle might do involuntarily, and thus increase its refractive power by augmenting the antero-posterior axis. A diminution of focal distance would hence result. The retina would be thrown backwards by the same action, and its power of receiving a distinct image from a near object enhanced considerably thereby. The elasticity of the sclerotic coat would increase the focal distance again on the cessation of the voluntary action of these muscles. This view was confirmed by the fact that a person was conscious of a voluntary effort in adjusting the sight to an object placed very near the eye, much more so than he would be to any effort in looking at a distant object. It had been supposed that the four recti muscles, acting together, might compress the globe and cause a shortening of the focal distance; Dr. Ashe considered that the only effect of such a cooperation would be to draw the eyeball back into the orbit, and, if anything, rather diminish the antero-posterior diameter of the globe; certainly they could not increase it unless they had osseous attachments anteriorly as well as posteriorly. But it had been demonstrated that the muscular fibres of the obliqui were continuous quite round the eyeball; and hence if they were to act together, as Dr. Ashe suggested, their effect would undoubtedly be to increase the antero-posterior diameter of the globe. To correspond with such a diminishing of the focal distance a slight approximation of the antero-posterior axes of the eyeballs would be necessary, and were this to be accomplished by the same mechanism the requisite correlation would be established between the two actions. This would be effected by the muscles in question if the point where their actions balanced each other were placed a very little anterior to that circumference of the eyeball which should pass through their fixed attachments, and this Dr. Ashe considered was exactly the position of their insertion into the sclerotic.

On voluntarily shortening the focal distance the pupil might be observed to contract, relaxing again when the focal distance was elongated; this seemed to corroborate Dr. Ashe's views, since the inferior obliquus and the circular fibres of the iris were both supplied by the third nerve, and might be simultaneously affected by its action.

In experimenting on the dead body, Dr. Ashe had found that, by the sense of touch, a distinct elongation of the antero-posterior axis of the eyeball could be recognized on drawing at once on the two obliqui; he had found the sense of touch the most delicate indication of the alteration.

On the Scientific Cultivation of Salmon Fisheries.

By THOMAS ASHWORTH, *of Cheadle.*

The main objects of this paper were to show the great value of salmon-fisheries, how they have been neglected in England, and how they might be improved. The produce of the English fisheries has fallen so low, that it has been estimated not to exceed 10,000*l.* per annum, and this including the fisheries of Wales, while the money value of the Irish, according to the reports of the Commissioners of Fisheries, is not less than 300,000*l.* yearly; one fishery in Scotland, that of the Duke of Richmond in the Spey, is said to return to his Grace 12,000*l.* annually. The author, in illustration of what may be accomplished for the improvement of salmon rivers, describes what has been done at his fishery in Galway, and the results. In the short space of ten years the river has been rendered ten times more productive. During the present season as many as 3000 salmon have been taken with the rod. This great improvement has been chiefly owing to the great care taken in preserving the streams during the breeding-season, at an expenditure of 500*l.*, and by introducing young salmon, artificially bred, into streams fitted for them, but from which the fish had before been excluded owing to impediments preventing access from the sea. These impediments have either been removed or avoided by means of ladders so constructed as to render the passage to and from the sea easy. A striking example is given by him of a river in Ireland converted into an excellent salmon river by means of ladders. This river is in county Sligo, the property of Mr. Edward Cooper. The ladders are over a fall of about 40 feet. So productive has this river, before barren, become, that in July last as many as 1000 salmon were captured in one week.

An Attempt to show that every living Structure consists of Matter which is the Seat of Vital Actions, and Matter in which Physical and Chemical Changes alone take place. By Professor Beale, *F.R.S.*

The object of the author was to show that every living structure was composed of matter that was "living" and matter that had ceased to "live"—of "*germinal matter*" and "*formed material.*" The first was alone the seat of purely vital phenomena, while in the formed material physical and chemical changes alone occurred. It was not possible to form any notion of the chemical relation of the elements of living matter. Neither could we obtain evidence as to the chemical character of the compounds of which living matter was composed. We could not obtain living matter in solution, and separate it again, as we could crystalline substances. The instant we commenced its chemical examination the particles ceased to be living, and the moment they ceased to live the elements *combined* to form certain compounds. The compounds did not exist as such in the living matter, but were formed the moment death took place. To understand these views, it is necessary to be acquainted with Dr. Beale's definition of the structure of a "cell."

At the last Meeting of the British Association, in Manchester, the author had endeavoured to prove that every "cell," or "elementary" part of a tissue, consisted of matter in two states—*forming, growing, active,* within; and externally of matter which had been in the first state, but was now *formed, and had ceased to be active.* The latter could be changed by external conditions, &c., but it had lost all inherent active powers of changing itself, or of communicating its powers to inanimate matter. All pabulum (nutrient matter) which was to nourish a living organism *must come into contact with the living or germinal matter.* Then, and not till then, it acquires the same properties; so that the living matter has increased in quantity in consequence of the inanimate pabulum, or certain of its elements, *being converted into this living matter.* Such a change never occurred in inanimate matter unless living matter were present. The greater the facility with which the inanimate pabulum came into contact with the living matter, the faster this increased. No matter how abundant the pabulum might be, if the living matter were surrounded by a thick layer of formed material, the living matter would increase but slowly.

It may be next inquired, What takes place during life in the smallest living independent particle, which consists of an envelope of *formed lifeless* matter, with living *germinal matter within*?

1. Pabulum passes through the formed material, enters the living particles, and reaching their centre, some of its constituents become living. Thus the quantity of the living matter is increased.

2. The new particles tend to move outwards from the centre where they became

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living, preceded by others which became living before them, and succeeded by new ones. Thus, during the life of a spherical particle, new centres are continually appearing in pre-existing centres.

3. The oldest particles on the circumference of the spherule, having passed through various stages of existence in moving outwards from the centre, gradually lose the power of animating lifeless particles, and become resolved into *formed material,* which is destitute of the power of increasing itself, and is no longer living.

4. The new-formed material is being produced upon the inner surface of that already formed—that is, in contact with the germinal matter; so that, passing from within outwards, we have (*a*) *germinal matter*; (*b*) *imperfectly developed formed material;* (*c*) *fully developed formed material.* The germinal matter exhibits in cases a central portion (*nucleus*), within which may be one or more portions with many circular outline (*nucleoli*), and within these smaller particles are often to be made out (*nucleoluli*). Passing from within outwards are several zones, the innermost being most intensely coloured by carmine.

The thickness of the formed material must gradually increase unless the oldest part which is outside is removed as fast as new-formed material is produced; in the latter case we should have (*d*) *disintegrating formed material.*

The conversion of inanimate matter into living matter, and the conversion of living matter into formed material, are continually taking place during life. The formed material, having been produced, is *passive.* It may be changed or altered, but it has no inherent powers of compelling the elements of matter to assume certain fixed relations to each other, like the germinal matter. It has ceased to live.

All the *work* performed by an organism during its life depends upon the action of certain agents upon this formed material. All these changes are physical and chemical, and can be caused to continue after the organism is dead; but the formed material itself can never be produced artificially, because its composition and properties depend upon the particles of germinal matter from which it was produced, and these derived their powers from pre-existing living particles, and these from their predecessors, and so on, back to the first living particle of that particular kind which was created. We can cause the *destructive* changes to continue after death; but the *constructive* changes cease with life, and cannot be imitated artificially.

The movements of living particles from centres, and the continual formation of new centres within pre-existing centres—the power of inducing similar changes in particles otherwise incapable of undergoing change—the progressive modifications taking place in a definite order, which end at last in the formation of passive substances having properties and chemical composition totally different from those of the pabulum on the one hand, and those of the living particles themselves on the other,—constitute a series of phenomena which occur in every different kind of living matter, and in living matter alone. They cannot be explained in the present state of knowledge by physical and chemical actions, and they may still be fairly termed *vital* phenomena, in contradistinction to those purely physical and chemical changes which occur in the formed material.

Living matter always possesses the power of *increase* and *formation,* and these processes of increase of the living matter, and its conversion into formed material, take place respectively under different circumstances. The conditions favourable to the increase of the living matter are not favourable to the production of formed material. Living matter may increase very rapidly, but the production of formed material is comparatively a slow process. All those tissues which in their perfect state are composed of much formed material in proportion to the germinal matter, grow slowly. During the earlier periods of their existence their growth was more rapid.

When a mass of germinal matter becomes surrounded with a thick layer of formed material, change, as would be supposed, goes on very slowly. The pabulum passes slowly through the formed material, and in small quantity, so that very little germinal matter is produced. The conversion of germinal matter into formed material, however, still proceeds until only a very small quantity remains living, surrounded on all sides by a thick, passive, and perhaps nearly impermeable en-

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velope. But suppose this envelope be ruptured, or softened, so that nutrient matter obtains more ready access to the living matter within, what happens? The germinal or living matter rapidly increases, and may even grow at the expense of the softened envelope itself. Masses of living matter are formed in great number, divide and subdivide, and perhaps multiply enormously, forming a solid mass, which may continue to increase for a time, but is incapable of lasting. The conditions favourable for the regular conversion of the outer particles of each mass into formed material are not present, and the whole mass may die and undergo disintegration and removal. Very many changes occurring in tissues in disease may be explained by these views. The power of living matter to grow infinitely is restricted by the conditions under which it is placed. Normally, growth may be slow; but if the restrictions be to some extent removed, then an abnormal freedom of growth may directly occur. This is exactly what happens in the process of inflammation. The germinal matter of the normal cells is more freely supplied with nutrient matter, and this often depends upon actual rupture of the envelope of formed material. These views, it will be observed, explain the phenomena of nutrition, growth, secretion, &c., without supposing any peculiar attractive power in the cell-wall, or any mysterious agency in its structure or in the nucleus; indeed, the existence of the cell, as it is generally defined, is dispensed with altogether. The author's "cell" is a mass of living matter surrounded by matter which had ceased to live, and which, like other inanimate matter, may be changed by physical and chemical agents. He reduces "*the action of the cell*" to the motion of living particles from centres where they become living, their passing through definite stages of existence, and their being ultimately resolved into substances exhibiting special properties, but lifeless. So he would explain the phenomena of inflammation, without resorting to the hypothesis of irritation, exaggerated action from external stimulation, &c.

According to the author's view, the most wonderful changes occur at the moment when the pabulum reaches the living centre, where its properties become completely changed, and where it commences its new course of existence. To account for the new powers which the particles have acquired, the author is compelled to assume the existence of a special force or power which can only be derived from particles which already possessed this power. He assumes that this power compels the elements of the pabulum to take up new and forced relations to each other, while, as they gradually cease to be under its influence, the elements resume their ordinary attractions, and special compounds are formed—the nature of the compound depending, therefore, upon the relations which the elements were constrained to take up during the living state. Hence he maintains that *vital power* exists in the particles of living or germinal matter, while the formed matter around this is destitute of vital power, and is only influenced by physical and chemical forces; and he thinks that while matter is in the state of living or germinal matter, it is in a temporary condition which is distinct and peculiar, and cannot be compared with any other state in which matter is known to exist. It is very remarkable that matter in this temporary condition exhibits the same appearance in all living beings, and possesses constantly an acid reaction. When set free, a mass always assumes a spherical form, and the smallest particles to be seen are still spherical. No one could distinguish by microscopical examination the "germinal matter" of one tissue from that of another, nor the germinal matter of one of the lowest, simplest organisms from that of man. And yet, although the germinal matter of all structures appears to be the same, it differs most wonderfully in power as seen in the results of its life. The formed material, on the other hand, exhibits, as we all know, differences of structure easily demonstrated, and differences of property familiar to every one; these differences being due to vital powers existing in the matter when in its previous state of germinal matter.

Some additional Observations on the Coloured Fluid or Blood of the Common Earthworm (Lumbricus terrestris). *By* JOHN DAVY, *M.D., F.R.S., &c.*

In this paper, supplementary to a former one on the same subject, the author, by varied experiments, some made *in vacuo*, some made in different gases, has exdeavoured to prove that the red fluid of the Earthworm is a receptacle for oxygen, and is thus subservient to the aëration or respiration of the animal.

Some Observations on the Vitality of Fishes, as tested by Increase of Temperature. By JOHN DAVY, *M.D., F.R.S., &c.*

The experiments described by the author were made on eleven different species of fish of our lakes and rivers, of which the several kinds of Salmonidæ were of the number. The results were that a temperature of water between 80 degrees and 100 degrees was fatal to each kind. The Salmonidæ were those which were most readily affected by elevation of temperature, the other species bearing it according to their kind somewhat better. The results generally were pointed out as of some interest in relation to the *habitats* of different kinds of fish, and also as tending to prove that the accounts given by travellers of fishes existing in hot springs are exaggerated, and not founded on accurate observation.

On the Question whether the Oxide of Arsenic, taken in very minute quantities for a long period, is Injurious to Man. By JOHN DAVY, *M.D., F.R.S., &c.*

In this paper the author gave an account of a small mountain stream in Cumberland, Whitbeck by name, which contains a minute quantity of arsenic, and which has from time immemorial been used by the inhabitants of an adjoining village, without any marked effect, either bad or good, on man and other animals, with the exception of ducks, to which birds the feeding in it has proved fatal. The author attributed the innocuity of the stream to two circumstances: first, the extremely minute quantity of arsenic present; and, secondly, the little tendency that arsenic has to accumulate in the organs of animals—the duck probably having less eliminating power than others. He mentioned instances in which arsenic in equally small quantity, derived from rivers in the Lake District, had proved fatal to the charr. He presumed that arsenic exists in many other streams, the water of which is used with impunity, the arsenic being derived from arsenical pyrites, a very common mineral, by the action of air and water, and, as in the instance of Whitbeck, comparatively harmless, and this owing to two circumstances—the very slight solubility of the oxide in cold water, and the fact of the harmlessness of the oxide in infinitesimal quantities.

Some Observations on the Coagulation of the Blood in relation to its Cause. By JOHN DAVY, *M.D., F.R.S., &c.*

These observations were chiefly made to test the hypothesis brought forward by Dr. Richardson, that the coagulation of the blood mainly depends on the escape of ammonia. The many results described by the author were opposed to this view. First, he showed that blood in its healthiest state contains no appreciable quantity of the volatile alkali; and, secondly, that ammonia added to the blood in a notable quantity did not arrest the change. Other experiments were described of a confirmatory kind.

The conclusion finally arrived at was that we are still ignorant of the cause of the phenomenon, and that the hypothesis of Dr. Richardson, if acted on in medical practice, must be attended with risk.

Remarks on the Loss of Muscular Power arising from the ordinary Foot-clothing now worn, and on the Means required to obviate this Loss. By JAMES DOWIE.

In wearing rigid-soled boots or shoes, the waste of muscular power is of a three-fold kind: *first,* that arising from atrophy, in which the locomotive function of the muscles of the extremities is reduced below its normal standard; *second,* that arising from the extra force exerted in bending comparatively rigid clothing; and *third,* that arising from the normal functions of the muscles of the feet when walking being partially or wholly transferred to those of the pelvic region or upper parts of the body. In each case the sacrifice sustained is shown to be manifest. The remedy proposed to obviate this threefold loss is the ingrafting of elasticated leather into the sole of the boot or shoe, between the heel and tread, under the instep, whereby the foot is allowed to perform with comparative freedom its natural movements in progression, and consequently the muscles to retain their normal health, strength, and usefulness. The soundness of this conclusion is confirmed by upwards of twenty-five years' experience in the wear of foot-clothing thus made. The elastic principle is shown to be a *sine quâ non*,—mere form, however adapted to the foot when in repose, being inadequate to obviate the loss of muscular power when walking. In illustration of the elastic principle, two strong Blucher boots were exhibited, the one made on Mr. Dowie's plan, having elasticated leather ingrafted into the sole, in contrast with the other, a rigid-soled "sealed-pattern regulation boot" as now worn by the British army.

On Pearls; their Parasitic Origin. By Robert Garner, *F.L.S.*

The author said he had particularly examined those formed in the mantle of the Conway and Lancashire mussel,—not the beautiful pearls of the *Alasmodon*, from the Upper Conway at Llanrwst, but those of the salt-water mussel: however, he attributes the same origin to all pearls, the oxidation of a minute species of *Distoma* causing their formation, much in the same way that galls are formed in plants.

On an Albino Variety of Crab; with some Observations on Crustaceans, and on the Effect of Light. By Robert Garner, *F.L.S.*

In four species of Crustacea which were observed, a splitting of the fore-claws at the third joint from the extremity took place during moulting, exactly as described by Reaumur, the line of splitting being afterwards with difficulty perceived in the cast shell. This splitting always takes place in the same line—a line noticeable in the shell of a crustacean not about to moult, at least in those species observed, as the Hermit-lobster. The author has rarely failed to detect the *Nereis bilineata* at the posterior part of the spire of the shell which is occupied by the latter animal, and many years back forwarded it to Dr. Johnston, of Berwick, to whom it proved an acquisition, and who believed it to be absent or rare on the Northumberland coast. The little living *Cancer pagurus* exhibited was found in the root of a *Fucus*, and when fresh moulted, which had happened several times during the last year, was white except the ends of the claws. With respect to the action of light, the author observed that some Actiniæ did not dislike it, whilst to others it was extremely distasteful; for instance, *Act. dianthus* to avoid it frees itself from its attachment and swims away like a Limnæus with its base to the surface, whilst the common Actinia seems to like it. As an example of the effect of obscurity on a vegetable, the author showed a curious specimen of the Clavaria form of *Polyporus squamosus*, which sprung from a piece of oak in an obscure part of an iron-forge. The Nereis above-mentioned seems sensible both to light and sound. The Crustacea in which the valve-like split (if split it can be called) was observed, were (besides the Hermit-lobster) the common and the shore crab, and the hairy Porcellana.

The Skull-sutures in connexion with the Superficies of the Brain. By Robert Garner, *F.L.S.*

If the mammalian skull may be considered as formed by the enormous development of the elements of several vertebræ, and if the vertebral medulla in fishes gives indications of its being composed of separate ganglia, then analogy would lead us to look in the brain for separate ganglia corresponding to as many vertebræ as form the skull, and also to expect corresponding dispositions in other respects—as regards nerves and their exit, the ventricles, and the form and distribution of the internal grey matter—all probably to be traced.

However, we now confine ourselves to those parts peculiar to the brains of the higher animals—the convolutions. These are not merely chance forms due to the errant meandering of arteries and veins; for though organs are built up by arteries, they are formed upon a preceding plan. The gyri or convolutions have a known disposition, corresponding more or less on each side in all brains, so that it is possible to trace out on paper what course the convolutions of a healthy brain will take—at any rate, the exceptions will be in small particulars; and this not in man only, but more easily as we descend through the inferior forms—the savage, the idiot, the chimpanzee, the monkey, the carnivora, and so on.

That portion of the skull occupied by the cerebrum proper may be divided into five surfaces—an ethmoidal, lodging the olfactory lobes, small in man, but ample in other mammalia, as the marsupial or elephant; a sphenoidal, to which the grey matter about the optic commissure and the island of Reil correspond; a frontal for the anterior lobes of the brain, temporal surfaces for its inferior tuberosities; a parietal for the vastly predominant superior middle portion; and an interparietal, corresponding to the posterior lobes.

Wishing to see exactly what gyri or sulci correspond to the sutures which divide the regions of the skull, and finding that this cannot by ordinary comparison be well done (our present modes of examination giving us anything but clear ideas of the topography of the encephalon), the author devised a plan of piercing the skull along the sutures, and marking the corresponding points of the brain by vermilion introduced by means of a grooved needle. He then extracts the brain, and lets it fall into a strong solution of corrosive sublimate, which has the effect of rapidly hardening it so that it will allow of a perfect cast being taken from it. The membranes may also be easily removed, though with more difficulty over the posterior lobes. Pins are introduced into the brain at the spots where the vermilion punctures are seen previous to taking the mould, which should be formed of two applications of the liquid plaster, the first most fluid and of little bulk.

With respect to the coronal suture, which appears to trend backwards in the greatest degree in the lower races of man, it will be found to correspond to a certain describable line. This begins before the first convolution above the commencement of the fissure of Sylvius, and rises, not along the oblique fissure of Rolando (separating the first from the second of those three remarkable oblique convolutions arising from the upper lip of the Sylvian fissure, and going upwards and backwards to the vertex), but more directly upwards, and more in front, before the anastomoses which the anterior oblique convolution has with the frontal ones. These frontal convolutions evidently run in a longitudinal direction in the adult, but more evidently so in the fœtal brain, well marking the frontal portion. Within the longitudinal fissure the separation of the frontal and parietal portions is commonly well marked in man, monkeys, and the lower mammalia.

The squamous suture corresponds to the fissure of Sylvius, which, as far as the external surface of the brain is concerned, may be said to commence about the summit of the great ala of the sphenoidal bone, which in some skulls (prognathous ones) does not always reach to the parietal bone.

A suture occasionally exists in the occipital bone, marking the posterior edge of the brain, apparently common in the American races, but not peculiar to them, as was seen from photographs of a Negrito and other skulls, illustrating the paper in this and other points relating to the skull, and kindly lent by Dr. J. Barnard Davis. This interparietal bone (the cerebral portion of the occipital) appears to be worthy of study; it is large in the inferior races of man, and also full in the female. The lambdoidal suture corresponds to the line which divides the convolutions forming the third lobe from the middle or parietal—a line commonly well marked on the brain surface, though not an uninterrupted sulcus; more strongly in the Quadrumana, but still more strongly internally in the longitudinal fissure. The inferior tuberosity of the brain is most intimately connected with the posterior lobe.

The parietal portion of the upper surface of the brain constitutes, of course, by far its largest region. Before, are some gyri already mentioned as being anastomoses of the anterior oblique parietal convolution with the frontal. These anastomoses, in combination with the inner frontal convolution, form in man a broadly halberd-shaped figure, the coronal suture crossing at a little distance before the handle as it were, but in many mammalia a broader trilobed figure like a club of cards or a fleur-de-lis. Behind, we have already described three more or less well-marked convolutions going from the fissure of Sylvius upwards and backwards to the middle line.

The middle one is always the most remarkable, and a fixed point for measurement: its termination in the longitudinal fissure is marked by a deep sulcus, forming the anterior boundary of a quadrangular surface, of which the posterior boundary is the sulcus already mentioned as marking the division of the posterior from the middle lobes of the brain. The oblique convolutions (with or without the anterior one, and with or without some anastomosing gyri going backwards from the middle to the posterior lobe) form a remarkable broadly triangular or rather bat-shaped figure, more remarkable still in the Quadrumana, and reminding us of the bat-like expansion of the sphenoidal bone below, and its corresponding cerebral surface. This, of course, is merely an accidental resemblance; but where we are not sufficiently advanced to make physiological divisions, such comparisons may be of use in studying "a mighty maze, but not without a plan," and fairly belong to topographical anatomy, serving, like language, to embody our observations, and eventually, conjoined with the comparison of the internal structure, or more definitely the course of the divergent prolongations of the medulla oblongata through the brain, leading to large results.

On the Physiological Effects of the Bromide of Ammonium.

By George D. Gibb, *M.D., M.A., F.G.S.*

After dwelling generally upon bromine and its salts, the author referred to the alleged properties of the bromide of potassium. This salt he had used, and it failed to produce what had been asserted of its powers. He had, however, changed the base to ammonium—the bromide of ammonium—carefully prepared in a pure form by Messrs. Fincham, of Baker Street, London; and on submitting a number of healthy persons to its use, a series of highly important results were obtained. These were detailed at some length, and the experiments described. The latter were not yet complete, but the author thought them still sufficiently important to bring before the Association.

The great tegumentary systems, both internal and external, were chiefly influenced by this agent, especially the former. The adipose structures came next under their influence. Its effects on the skin justified its being considered a cleanser and beautifier of the complexion. It restored secretion to the mucous membrane, and according to the mode of its administration and the susceptibilities of the individual, so did it produce anæsthesia, especially noticeable in the fauces and throat. The membrane of the nose, the pharynx, the larynx, and bronchi, as well as that of the eyes and ears, were subject to its influence; and in the course of his experiments, the author found that the entire tract of the genito-urinary and gastro-pulmonary mucous membrane was occasionally, not always, brought under the control of this agent. It also exerted a peculiar and specific effect upon atheroma and fat; and if administered sufficiently long, and in proper quantities, it will slowly remove corpulency and allied states through the blood. Fatty changes in certain organs, such as the heart and its vessels, are arrested by it; and the author believes it would equal, if not surpass, the *Fucus vesiculosus* in some of its alleged virtues.

The author intended to continue his investigations.

On the Normal Position of the Epiglottis as determined by the Laryngoscope.

By George D. Gibb, *M.D., M.A., F.G.S.*

After some remarks upon the various hypotheses which have been brought forward by physiologists on the mechanism of the voice, which the author considered somewhat conjectural from the absence of ocular proof, he referred to the introduction of the laryngoscope as likely to determine the true nature of phonation and other phenomena connected with the larynx. Whilst not unmindful of this himself, he had devoted some attention to the inspection and study of the parts above the glottis, especially to explain anomalous sensations there experienced. For this purpose he had examined the throats of healthy persons with the laryngoscope, so as to become familiar with the parts in them. Up to the date of his communication he had examined 300 individuals, and his results were confined mostly to the condition and position of the epiglottis, which were so important that they had led him to form certain conclusions.

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The author referred to the commonly accepted views in relation to the normal position of the epiglottis being considered wholly *vertical* or erect, and quoted Harrison, Knox, Bishop, Dunglison, Meckel, Cloquet, and even Czermak, in support thereof. Whilst admitting their correctness to a certain extent in the largest portion of mankind, he has discovered, in the course of his physiological investigations with the laryngoscope, that in eleven per cent. the epiglottis is not erect, but either oblique or nearly transverse, and that this condition is not necessarily associated with disease, occurs at all ages, and is occasionally congenital, being observed in parent and offspring. The ages of those examined varied from 6 to 90 years.

The effect of this position of the epiglottis is an alteration in phonation, and much inconvenience and danger in the event of disease, as well as inducing a predisposition to take on diseased action. Speaking and singing are much affected; some cannot sing in consequence. The shape and condition of the valve named in the 300 persons examined were then described.

The author summed up with the following conclusions:—

1. Physiologically speaking, the epiglottis is vertical in the great majority of mankind; in a certain proportion it is oblique or nearly transverse.
2. The evils likely to arise from the latter at present appear to be so inconvenient, that it would be desirable that an inspection of the epiglottis should be made in every child, where practicable, between the ages of 6 and 10 years, for the purpose of ascertaining its correct position.
3. If it is found to be not vertical, a knowledge of the fact will prove beneficial through life in guarding against evils likely to arise, during the prevalence of epidemic sore-throat, or other diseases likely to involve the larynx.
4. No interference with the throat or larynx should ever be permitted without the aid of laryngoscopic inspection.
5. Whilst any imperfection in the voice or speech may be explained by the position of the epiglottis, independently of the vocal chords, a chance for the improvement of both is held out, by adopting some means that shall render this valve more oblique in direction than transverse, or possibly (but at present very doubtful) restore it to a vertical position.

On Secret Poisoning. By GEORGE HARLEY, *M.D., Professor of Medical Jurisprudence in University College, London.*

The author stated that although he had no wish to engender groundless suspicions or excite unnecessary alarms, yet he was sorry to say he could not but repeat the statement he made last year in a paper on slow poisoning read before the Royal Medico-Chirurgical Society of London—namely, that he believed the cases of secret poisoning that are discovered form but a small percentage of those that actually occur. Nay, more, he even went a step further, and declared that he not only believed that we magnified the difficulty of perpetrating the crime, but that we were also inclined to exaggerate the facility of its detection. No doubt, modern discoveries in physiology and chemistry had enabled us not only to distinguish between the effects of poison and natural disease during life, but likewise to detect and extract the poison from the tissues after death. But modern discoveries had also made known to us many poisons with which we were hitherto unacquainted. It was in toxicology as in naval warfare, no sooner was a projectile discovered that is considered irresistible than our engineers set about discovering armour-plates more invulnerable than their predecessors. So, no sooner does the criminal find a new poison that he can use with impunity, than the experts set about discovering a means for its detection. He remarked that the great desire of the poisoner was to get hold of a poison the effect of which would so closely resemble that of natural disease as to be mistaken for it. Fortunately, however, this was attended with extreme difficulty, as the effects of poison were generally sudden in their onset and rapid in their termination; for the poisoner seldom had time or opportunity of administering the poisonous agent in so small a quantity and for such a length of time as are requisite to produce an artificial state of disease which may be mistaken, at least by the unaccomplished physician, for real disease. It had been asserted that in all cases of poisoning where death occurred, the poison ought to be found in the tissues after death. He, however, pointed out that this was not strictly true: for even in the case of arsenic, which was supposed to be the most persistent of all poisons, if the patient only lived long enough, the mineral might be entirely eliminated by the excretions before death, and afterwards not a trace remain to be detected in the body. Such occurred in Alexander's case, when, although it was known that arsenic was the poison which caused death, none was found in the body. Alexander, however, did not die till the sixteenth day. For this and other reasons the author then said, "that as the not finding poison in the system after death is no absolute proof that the patient did not die from its effects, the symptoms observed during life, in conjunction with the morbid appearances observed after death, even when no poison is discovered by chemical analysis, ought to be sufficient to convict the poisoner; and even the symptoms alone, if there be good circumstantial evidence, especially if combined with proof of a motive, ought to convict, just as was done at Palmer's trial." The author concluded by saying that in all cases of suspected murder, great care should be taken to avoid telling the persons around the patient of the suspicion. The patient himself should be the first confidant; for if there was no motive for suicide, he was the most likely to be aware of a motive in the persons surrounding him. The next confidant should be the doctor, who, by obtaining some of the secretions and having them carefully analysed by a competent person, would soon be enabled to decide if it was a case of secret murder, and perhaps also give a clue to the detection of the criminal.

Suggestions towards a Physiological Classification of Animals.

By James Hinton.

It is scarcely necessary to remark that no system of animal classification has yet been accepted as entirely satisfactory, or that it is universally allowed that no linear series can possibly fulfil the requirements of the case. As bearing upon this subject, the author's attention has been drawn to the relation in which the Articulata and Mollusca stand to each other. It is manifestly impossible to place either group, as a whole, below the other; but there exists a marked *physiological* difference between them. In the Articulata, for instance, the organs of animal life preponderate, and give a decided character to the group, while in the Mollusca the organs of vegetative life are not less strikingly predominant. The two classes might well stand as representatives of the two great elements in which animal life consists. With this thought in mind, it appeared to the author that the whole animal series arranged itself (with certain difficulties and doubtful points of course, but still on the whole very readily) in conformity with this idea. Thus, for instance, between reptiles and birds a similar relation obtains.

The author further illustrated his views by reference to other classes.

On Simple Syncope as a Coincident in Chloroform Accidents.

By Charles Kidd, *M.D., M.R.C.S.*

At two former Meetings of this Association, several reasons, chiefly obtained from the large field of clinical experience of London hospitals and their operating theatres, were stated, and given in detail, why we should regard deaths from chloroform administration as pure accidents; and deaths in hospital, as not to be considered exactly similar to deaths from overdoses in lower animals. The author is desirous at present to state, that the leading facts and reasonings then expressed have since been borne out by further experiments and explained, but that at the time part of the subject was purposely left incomplete.

There is reason to believe that a large percentage of so-called chloroform deaths arise from simple fainting-fits, or "shock" (as known long before chloroform was discovered at all), but that *now* chloroform gets the discredit of them. The deaths from sulphuric ether used as an anæsthetic (at least twenty-five in number) were nearly all the result (most probably) of secondary hæmorrhage after operations, which it very much favours, as also a state of deep narcotism like that from morphia, previously misunderstood, and therefore not guarded against in sufficient time to save life. The accidents from simple syncope are of the nature of accidents after chloroform—*post hoc*, but not *propter hoc*; they are very alarming, more so than the asphyxia cases, as it is very difficult to rouse up the reflex and cardiac nerves where syncope occurs, and, curiously enough, it seems to occur by emotion or fright irrespective almost of the chloroform.

The author, being a believer in the value of the deductive philosophy of Mr. Mill and Mr. Buckle in inquiries, like the present, of a physiological kind, wishes at present simply to state that he finds the immense mass of facts as to chloroform (chiefly experiments on the lower animals instituted by the Biological Society of Paris, as detailed in the very masterly essay of MM. Lallemand, Perin, and Duroy—a mass of facts of the highest importance, only very recently published) entirely agree with and corroborate the clinical views he had the opportunity of laying before this Association.

It is a pleasure to be able to state, that every year's additional study of chloroform in London leads to a feeling of greater and greater satisfaction as to its value and safety; that this impression also agrees with clinical experience in other cities of Europe, and even in America, where chloroform has now nearly superseded the use of ether.

The author wished the present paper to be short, to be, in fact, complementary of former communications. The aggregate number of deaths from chloroform is very alarming; but there is reason to think that, in nearly all the cases, the points here discussed previously, as to the necessity of good respiration, good pulse, &c., still hold good for all cases. It seems very desirable that the results, however, of the hospital experience of the members of the Physiological Section of this Association could be obtained as to any new facts or observations that may have come under notice; for the entire subject of anæsthetics is, as yet, but in a tentative or rudimentary condition.

The physiological data of former discussions were left unsettled and incomplete, as said already, in order that a more full consideration might be given to the exact value of simple syncope as a source of danger.

The discussion hitherto, in Dr. Snow's time, as to the nature of death from chloroform, with the consequent precautions to be observed to ensure its safety in practice, had been almost entirely confined to an examination of one question—whether these accidents arise from what the late Dr. Snow named "cardiac syncope," with engorged state of the right side of the heart, or from simple syncope, the right side not engorged.

The more philosophical mode of regarding the subject now is to look on *both* causes as active: the "cardiac syncope" is a post-mortem result, however, as it is described by Snow, and is in reality death from apnœa or asphyxia, and arises in some manner, most probably from some error in the administration of the chloroform; but the second cause of death, or simple syncope, is due to idiosyncrasy. This advance in our knowledge is of importance as to saving life in these cases: we were before looking, like the knights of old, at only one side of the shield, but now we know the shield has two sides.

Having previously described at Oxford the mode in which accidents, by asphyxia or "cardiac syncope," occur through irritation of the laryngeal recurrent nerve, or other more recently described nerves, distributed to the mucous membrane of the larynx and air-passages ("Rosenthal's nerves"), it is only necessary to state that further experience helps to corroborate this view. This form of death by asphyxia or apnœa arises by stoppage of action of the respiratory muscles and diaphragm, and can also be brought about in experiments on the lower animals by any even mechanical irritation of these laryngeal nerves; hence the grave necessity of care, in the early stages of the chloroform administration, not to excite or irritate the larynx by acid or impure chloroform, which, like some gases, at once induces spasm of the glottis, with subsequent signs of asphyxia. This was fully entered into at the Oxford Meeting.

Indeed, so sensitive is the larynx, and so peculiar its tolerance of chloroform, that this fact of the irritation of its mucous membrane by a strange vapour is now taken advantage of, and where we have to fear simple syncope or faintness, as in formidable operations like ovariotomy, and where syncope is impending in the middle of such operation, the addition of a drachm or two of ether to the inhaler, or a few drops of ammonia, seldom fails to rouse the most flagging pulse (as easily conceivable) through these very nerves. Explain it how we will, the clinical fact is of the utmost importance.

This is shown in another direction in this manner:—if we render an animal deeply narcotic by chloroform, in fact all but dead, and then allow it to come back slowly to its usual condition, there is one point where, if the laryngeal nerves be pinched with a forceps, it causes sudden spasm of the glottis, the diaphragm stops acting, and, for want of breathing, the animal falls back again into a state of narcotism or asphyxia, and may die.

With this recent discovery as to these nerves we may perhaps couple the group of facts that there is greatly increased danger attached to surgical operations about the larynx or neck (as observed in practice), arising from cutting or injury of its nerves, or catching them up in forceps whilst tying arteries, &c., some intimately associated with nerves of the cardiac plexus, others with the larynx itself, &c.

If the act of breathing freely continues during the administration of chloroform, we may be almost certain all is right, and the pulse good; but if the breathing becomes slow or intermittent, stopping and going on again, we are not so safe. Some patients, it is true, seem to take the chloroform slower than others, but it is a fatal error to push it on; the chloroform will accumulate in the system, and the after-effects will be tedious, if the surgeon, for want of time or other causes, hastens the administration.

Is death from chloroform, so called, sometimes a coincidence?

It is well to remember that very marked syncope, and even death from syncope, may occur without the use of chloroform at all: intense sudden pain may cause death and syncope; injury of a tendon, or a large bleeding, or even such a trifling thing as touching the urethra in sounding for stone (as remarked especially by Heurtaloup), may induce most alarming syncope; great weakness from want of food, as in soldiers sometimes after a battle, will also give a great tendency to syncope: so that it is always of advantage to learn more or less of a patient's history when we are about to administer chloroform.

Accidents from syncope and chloroform may occur from *apprehension* of pain rather than actual shock, or actual pain, or deep chloroform narcotism; hence so many accidents in the early part of the administration, before the patient is unconscious at all. Thus of 125 deaths carefully analysed, fifty-four occurred immediately before operation, forty-two during operation, but none as the result of long-continued narcotism or anæsthesia; yet chloroform has now to bear all the obloquy of all fatal accidents in the operating-theatre, a certain large percentage of which are obviously the effect of purely mental causes or fear.

Persons with strangulated hernia, about to be operated on, are known to have died before any incision at all (without chloroform), the patients taking the shaving of the pubis for part of the operation. Bichât saw a patient die on the instant of passing a simple seton. Dr. Watson tells of a patient dying suddenly at the sight of a trochar about to be used in tapping the chest. Desault was one day about to perform the operation for stone; the patient did not present anything unusual in his manner, and was placed in the usual position: Desault traced simply a line with his thumb-nail on the perineum; the patient uttered a shriek, and fell stone-dead. Mr. Stanley used to tell of a similar case—Chopart was about to operate for circumcision on a lad, when the boy fell dead the instant the knife touched him. Garengot had a patient with a thecal abscess, who had a shudder and sudden death on seeing the tendon move.

Syncope thus becomes a complication, in modern surgical operations, of much greater seriousness than before. That death occurs not from over-narcotism is at once evident, as it arises from apprehension of pain, *the patient being quite conscious when these syncope accidents have occurred.*

These deaths (and they amount to about thirty in the hundred of all the deaths) are observed to happen while the patient is having the chloroform administered before the surgical operation (at sight of knives, saws, surgeons' aprons, a crowd of students, dressers, strangers, &c., in the operating-theatre), showing how much wiser 's to have the patient placed under chloroform in the sick-ward, than to be exposed ·is mental shock. In some London hospitals it is so, in others the point is not understood; but careful observation leaves no doubt on the author's mind that, next to apnœa or asphyxia, already minutely dwelt upon, this mere coincidence of simple syncope is most to be dreaded.

Observations made at Sea on the Motion of the Vessel with reference to Sea-Sickness. By J. W. Osborne.

The author stated that he had entered upon this investigation during a voyage from Melbourne, not with the interest of a physician, whose object it would be to cure this distressing malady, but rather for the purpose of establishing the nature of the connexion between mechanical movement of the human body, both active and passive, with the phenomena of nutrition and waste, functions which manifested many interesting and remarkable anomalies during an attack of sea-sickness.

Many observations of a pathological and physiological character had been made and recorded; but it soon became apparent that to obtain results of real value, the nature, force, and direction of the movements to which the vessel subjected the body, and its several organs, required investigation. To express these mechanical influences, three instruments were contrived and used with satisfactory results. These instruments were exhibited by the author, and the following is a sketch of the description given to the Section.

The first consists of a spring balance, capable of suspension from any part of the ship. By placing a known weight in the pan of this instrument, the deflection indicated by the index would be constant under ordinary circumstances on shore. At sea this was not the case, the pan being there subjected to an unceasing oscillatory movement, while the index indicated at one time more, and at another less than the figure on the scale corresponding to the weight used.

The range thus obtained depended chiefly upon the severity of the pitching; and if the divisions of the scale represented fractions of the weight used, the alteration in weight of any of the viscera of the human body, with every wave, might be arrived at in fractions of their own weight; such alteration being, of course, apparent only, but acting, nevertheless, upon all supporting ligaments, muscles, &c. exactly as if it were real.

It was well known that the pitching motion of a vessel was very potent to produce illness, and in the instrument exhibited, the means were offered for measuring and expressing exactly the intensity of this motion; but it was necessary while recording these readings, to determine what the angular movement the vessel made amounted to. To effect this a divided arc was made use of, which, while its manner of suspension permitted of its accommodating itself to one of the angular motions of the ship, partook for the time being of the other. Opposite to this arc, and from the centre of the circle of which it was a part, a plummet or pendulum, made of a strip of metal, was freely suspended. The part played by the latter was to establish a point from which to read off the number of degrees through which either axis of the vessel passed in pitching or rolling. But as the inertia of the pendulum caused it to be seriously affected by the impulsive movements to which the vessel was subjected in passing through the water, it became necessary to neutralize these irregularities. This was accomplished by placing in rigid connexion with the pendulum a small disk, which travelled through a curved tubular receptacle containing oil, glycerine, or other viscid fluid, which, while it did not interfere with the obedience of the plummet to the action of gravity, effectually prevented the communicated impulses from manifesting themselves in the readings.

The third instrument was designed to estimate the force of the impulsive movement above referred to, and was an arrangement of a somewhat complicated character, in which the oscillations of a pendulum, unaffected by the angular movements of the vessel, were read and recorded. These oscillations originate in consequence of the inertia or momentum of the pendulum itself, freely suspended in a ship varying in its rate of motion through the water.

Several extended series of observations had been made with these instruments which were not as yet reduced.

On Tobacco in relation to Physiology. By T. REYNOLDS.

The author commenced his paper by adverting to the value of saliva, which he averred was intended for the purposes of digestion, and ought not to be unnecessarily wasted, which was the case with a vast number of habitual smokers. The purity of the saliva ought to be preserved, which could not be the case if it were tainted with smoke. He pointed to the fact that the people of Israel, as we read in Holy Writ, were not an enfeebled race, because they did not infringe natural laws. The paper proceeded to quote the names of various medical men who were opposed to the practice of smoking; some avowing that tobacco-smoke, being conveyed into the stomach, injured the brain. One doctor had seen leeches fall dead when sucking blood from the veins of a man who smoked, the blood of the smoker being much more impure than that of the non-smoker. Dr. Copland avowed that smoking arrested the growth of the young. Dr. Seymour, in writing to the Earl of Shaftesbury, stated that smoking was a remote cause of insanity, and produced premature constitutional decay; in fact, smoking was attended with many unfortunate tendencies.

On the Study of the Circulation of the Blood. By GEORGE ROBINSON, *M.D., Fellow of the Royal College of Physicians of London, &c., Newcastle-on-Tyne.*

The writer commenced by observing that Harvey having established the general law of the circulation of the blood, and expressed an opinion that all the secondary functions depended on it, left to posterity the task of investigating its mode of action in inducing the other phenomena of life. But while every succeeding generation has furnished fresh proof of the importance of this discovery, comparatively little has been done towards elucidating the manner in which the motion of the blood acts in the production of its numerous and diversified effects, although the actions directly dependent on it are not only physiologically interesting, but also play an important part in the production and removal of disease.

Among the causes which have interfered with the proper development of Harvey's views, the writer notices the undue prevalence of a metaphysical physiology, and a consequent disregard of the legitimate application of the principles of physical science to the explanation of the actions of the living body. He contends that this preference of the ideal to the real still operates to some extent in the same manner as when Harvey's hydraulic reasoning shocked the prejudices of his contemporaries, and that the doubts still occasionally expressed as to the sufficiency of the heart as the prime mover of the mass of blood, the assumed existence of undemonstrable adjuvant forces, and the affectation of incredulity as to the applicability of the laws of hydraulics to the solution of the physiological questions directly connected with the blood's motion, all evidence the injurious effects of the continued neglect of natural philosophy as a branch of medical education, and the retarding influence on medical science of such inattention to the physical agencies operating in the performance of the vital functions. In further confirmation of this opinion he alludes to the fact that certain views as to the mechanism of vascular absorption and effusion, which he published many years since as the result of an attempt to explain on hydrodynamic principles some of the uses of the circulation, have neither been received nor refuted by the systematic writers on physiology, who are still satisfied with old doctrines on these subjects, applicable only to stagnant liquids, and quite incapable of accounting for some of the phenomena in question. He then asks on what other principle of research than that adopted by Harvey himself can we ever hope to understand the action of the currents of blood in accomplishing their various uses; and refers to the evident subservience of the structural arrangements and physico-vital peculiarities of the organs of sight, hearing, respiration, speech, motion, &c., to the physical principles involved in each particular function, as a proof of the operation of the general laws of matter in the living body, and of the consequent applicability of hydrodynamic reasoning to the explanation of many of the uses served in the animal economy by the innumerable streams of blood incessantly permeating the tissues.

In the application of these principles, it is essential to observe closely the physical and vital properties of the living structures, and to combine, if possible, the knowledge and labours of natural philosophers and physiologists. He therefore concluded by submitting to the Council of the British Association the propriety of appointing a subcommittee to cooperate with the Royal College of Physicians of London (who are specially interested in everything relating to Harvey's fame), for the purpose of investigating the physics of the circulation, and so rendering more intelligible the nature of the connexion existing in the living body between the motion of the blood and the performance of the secondary functions of life.

On the Difference of Behaviour exhibited by Inuline and ordinary Starch when treated with Salivary Diastase and other converting Agents. By Professor Rolleston, *M.D., M.A., F.R.S.*

The following were the chief results to which Prof. Rolleston had arrived:—

I. Inuline from the Dahlia retains sugar with great tenacity, but, by repeated washings, it can be freed from that impurity.
II. When thus freed from sugar, it obstinately resists the converting influence of salivary diastase.
III. This salivary diastase was obtained from human saliva, and from parotid- and submaxillary-gland substance infused with water and buccal mucus.
IV. The same salivary diastase instantly converted ordinary starch into grape-sugar.
V. This salivary-gland infusion, however, if made with salivary-gland substance from young animals yet sucking, Dr. Rolleston had found to be ineffectual upon ordinary starch. Bidder's researches were in accordance with his.

These results led to the two following practical rules:—1. Artichokes are little likely to act as a substitute for the potato, as they contain inuline *vice* starch. 2. Starch-foods are useless in the early months of infancy, as salivary diastase at such a period is inactive.

Tobacco-Smoking: its effects upon Pulsation. By Edward Smith, *M.D., F.R.S., Assistant-Physician to the Hospital for Consumption, &c., Brompton.*

Dr. Smith had recently made a series of observations, chiefly upon medical men, which showed that in some persons tobacco-smoking greatly and rapidly increased the rate of pulsation.

The experiments were made at 10 P.M., when the rate of pulsation naturally declines (as he had proved by hourly experiments published in his work on the Cyclical Changes of the Human System), and at least four hours after any fluid or solid food had been taken. They were made in the sitting posture, after it had been maintained fifteen minutes, and with the most absolute quietude of body and mind; and thus all influences were eliminated but those due to the tobacco.

The rate of the pulsation was taken every minute for a period beginning two or three minutes before the smoking began, and continuing during twenty minutes, or until the pipe was exhausted.

The following are the chief results obtained:—

Experiment 1.—Pulsation before smoking was 74½ per minute.
Smoking 6 minutes, 79, 77, 80, 78, 78, 77 per minute = 78·1 average.
Smoking 7 minutes, 83, 87, 88, 94, 98, 102, 102 per minute = 93·4 average.
Smoking 8 minutes, 105, 105, 104, 105, 105, 107, 107, 110 per min. = 106 average.
After smoking 11 minutes, 112, 108, 107, 101, 101, 100, 100, 100, 100, 98, and 91.
There was thus a maximum increase of 37½ pulsations per minute.

Experiment 2.—*Smoking through camphor julep in a hookah.*
Pulsation before smoking 79½ per minute.
Smoking 6 minutes, 81, 81, 81, 83, 82, 82 per minute = 81·6 average.
Smoking 17 minutes, $\left\{\begin{array}{l}85, 89, 89, 93, 96, 90, 94, 94, 93,\\ 92, 95, 95, 95, 96, 94, 97, 93 = 93.\end{array}\right.$
The maximum increase was 17½ pulsations per minute.

Experiment 3.—*Smoking an empty pipe.*
Pulsation before smoking 78 pulsations per minute.

Smoking 11 minutes, 76, 78, 77, 76, 79, 79, 80, 80, 79, 78, and 79.

There was no increase in the rate of pulsations from the effort of smoking or from its interference with the respiration.

Experiment 4.—*To ascertain if after smoking* 6 *minutes, during which the effect is very small, and then ceasing smoking, any increase in the effect would follow.*

Pulsation before smoking 75 pulsations per minute.
Smoking 6 minutes, 76, 75, 79, 79, 76, 78.
Smoking 1 minute, 82.—Cease smoking.
Smoking 10 minutes, 81, 88, 83, 82, 84, 83, 83, 80, 82.

The rate of pulsations was maintained, but was not materially increased.

Experiment 5.—*To prove if the rapidity of smoking causes a variation in increase of pulsation.*

a. Greater volume of smoke.

Pulsation before smoking 70½ per minute.
Smoking 6 minutes, 68, 70, 71, 70, 72, 74=70·8 average.
Smoking 6 minutes, 76, 77, 86, 89, 91, 94=85·5 average.
Smoking 4 minutes, 98, 95, 96, 95=96·0 average.

The maximum effect was thus 27½ pulsations per minute.

b. Smoking faster.

Pulsation of the last minute in the previous part of this experiment, viz. 95 per minute.—Smoking 3 minutes, 94, 94, 96.

c. The pipe recharged.

Smoking 5 minutes, 87, 93, 96, 96, 96.

There was therefore a large effect upon the pulsation, but probably not more than would have occurred with ordinary smoking.

Numerous other experiments were made with tobaccos of different reputed strengths and upon different persons, and the author gave minute directions as to the proper method of making such inquiries.

GEOGRAPHY AND ETHNOLOGY.

On the Civilization of Japan. *By* Sir R. Alcock.

The author began by observing that "mankind," it had been said, was going through a great fusion. It was being made one, not by conquest, not by the spread of a creed, but by the interchange of commodities, a proposition which it was to be feared could only be accepted as true in a very qualified sense. Commerce and the natural wants of mankind were no doubt efficient agents in bringing different races into communication with each other—opening up new countries, and predisposing populations to spread by intercourse, by the interchange both of products and of ideas. But it was not the less true that commerce only opened the way, and quite as often excited jealous fears and gave way to hostile feelings, ending in conquest or civil convulsion and bloodshed. The tendency of the present day was rather to attribute too much to commerce as an efficient agency whether for civilization or peace. It often brought two totally dissimilar races into sudden contact in the aggressive march of western civilization and commerce eastward, and very seldom without collision and conflict. Between the moral and the physical there was in this, as in other directions, a great analogy. In the material world new forms and combinations were seldom effected without much effervescence and disintegration. Many dangerous elements were set free, and others which gave solidity and permanence disappeared. So it often proved when new elements of thought and civilization were brought into contact with the elder Asiatic forms of social life and government. So it had been in China as in Japan; the feudal nobles of the latter empire, with a true instinct, saw that commerce never came alone, but brought in its track germs of social and political change which, sooner or later, would destroy the feudal power and institutions. These had existed from time immemorial, and under them the nation had increased in numbers and in wealth, preserved its independence, and been self-sufficing. They saw in the new treaties, therefore, and the commerce they were intended to promote, an element of revolution, and were prepared to resist to the death, and strike while it was yet time. Commerce in this instance, as in a thousand others, so far from promoting peace, was pregnant with danger, and to all appearance would sooner or later lead to war, and this however little the merchant might desire such a result, or governments might seek to avert it. Commerce, in truth, originated a movement which not all the merchants in the world could arrest until its destined course was run. Western Powers, and we especially, entered into treaties with Eastern Potentates in perfect good faith, desiring only commerce, and hoping peace and civilization with the blessings of true religion might follow in the train. Such was not the lesson that the history of the world gave. Theory and experience were wofully at issue, and for once it would be well that experience should triumph over hope; for the first gave useful warning, while the latter only deluded by vain expectations. It was under this aspect that it became a question of deep interest what affinities or analogies might be found between the European and Japanese civilization now so suddenly brought into contact, or what elements of repulsion might be existing and active; for on this, to all appearance, would depend the issue, whether peaceful or the reverse. To speak of Japanese civilization was to speak of the whole life and development of a nation; and there was as much difference between nations as individuals. Sir Rutherford then showed that there were great vagueness and diversity of opinion as to what constituted civilization. The necessity of a clear definition was obvious; and by reference to the chief agencies employed, we should be able to discriminate between different kinds of civilization and degrees, and thus arrive at a rough basis of classification. Man's first triumph was that of physical force and intelligence combined over inanimate nature; his next, and by the same means, was over the higher animals of his own species! All the earlier forms of civilization were of this kind in various degrees. When it was proposed to govern man by argument rather than by force, by considerations and by motives addressed to his reason and conscience rather than to his fears, leaving him the full development of his faculties and the free use of all his energies, then civilization took its best and highest form. But of this civilization there was very little, even in the western world, as yet. We should be prepared, therefore, to estimate modestly any benefit in our power to confer on a race like the Japanese by introducing our civilization and institutions into Japan, and we should be patient if we saw that the Japanese adhered with tenacity to their feudalism and autocratic forms of government, and not only wished none of our novelties or innovations, but, on the contrary, were ready to do battle rather than permit the fine edge of the commercial wedge to be inserted. They (the Japanese) might tell us with truth that for centuries they had possessed, under their own laws, customs, and institutions, a degree of peace, prosperity, and freedom from foreign wars which no country in Europe had enjoyed any single century of its existence, with all our boasted civilization. How the civilization of a people might most readily be estimated was a question of some interest. Mr. Meadows, in his work upon China, suggested that the style and character of a nation's architecture (exclusive of edifices for warlike purposes), the roads, means of communication, and adaptation for travelling were the best criteria. This seemed doubtful. In Japan the soil was afflicted with a sort of quotidian ague by reason of earthquakes, and in architecture, as also in roads, the Japanese might vie with the Romans, so admirably were they engineered and maintained. But when we come to their ordinary means of travelling and communication, they sink far below the lowest of European States. A naked foot-runner made their post; a buffalo car, or an equally clumsy machine, carried on men's shoulders, was their usual conveyance; and this despite their knowledge by working models and books of our system of railroads and telegraphs. It was evident all these criteria could only furnish very fallacious data for judgment; for in other directions—in their conquest over matter and their progress in all the industrial arts—they might vie with the most advanced nation in Europe. In all the mechanical arts the Japanese had unquestionably achieved great excellence. In their porcelain, their bronzes, their silk fabrics, their lacquer, and their metallurgy generally, including works of art, in design and execution they not only rivalled the best artistic works of Europe, but could produce in each of these departments some of those of Europe. It was quite true that Europe might also make a similar boast with justice, for there was much, especially in the province of art properly so called, to which the Japanese could not make the slightest pretensions. They could not produce such works of art as might be seen in the International Exhibition in *repousse* from the chisel of a Vechte and a Monti. Neither could they rival a Landseer or a Rosa Bonheur. Indeed, they were wholly ignorant of oil painting, and no great adepts in water colour. In the outlines of animals, however, they had a most facile pencil. In enamels, in the manufacture of steel, and in silk fabrics, they could compete with the rest of the world, as also in their finer and egg-shell porcelain. The tendency of their government unfortunately, under a feudal rule and a feudal aristocracy, was utterly repressive of all free action or development of the faculties. Any evidence of individuality and originality would be fatal to a Japanese under the worse than Venetian rule of feudal chiefs. This was the one great obstacle to the development of commerce and the maintenance of peaceable relations; for the privileged classes, composed of some 600 daimios, and their feudal retainers, comprising an army of some 200,000 men, sworn and ready to obey all the behests of their chiefs, held the whole population in the most absolute subjection. And the hostility of these armed classes was neither to be softened nor conciliated. They foresaw, or thought they did, in the train of foreign trade, elements threatening destruction to all the institutions of the country, and foremost of these the feudalism which constituted them lords of all the soil and absolute rulers. This was the more to be regretted because the Japanese as a people had no hostility to foreigners, and were possessed of so many excellent qualities and such an aptitude for a higher civilization than they had yet attained, that within a very few years not only might we see them make a great and exampled advance, but a trade developed to which it was really difficult to fix any limit.

On the Climate of the Channel Islands[*]. *By* Professor ANSTED, *F.R.S.*

GUERNSEY.

The climates of the Channel Islands are so essentially different both from those of the adjacent lands of France and England and also from each other, and they offer so many points of interest connected with the influence of the Atlantic current on climate, that they deserve special attention. Its relative position marks out Guernsey as the typical island, and observations justify this conclusion. It is, therefore, fortunate that the elements of the climate of Guernsey have been better established than those of the other islands. Dr. Hoskins, F.R.S., is the observer to whose labours these valuable materials are due. The annexed Table gives these results to the end of 1858. Since then the weather has been exceptional.

Compared with Greenwich, the results are very interesting.

1. *Temperature.*—The mean annual temperature is 51½°, and the annual means in sixteen years have at no time exceeded this by 2°, or fallen short of it by 1½. At Greenwich the adopted mean temperature being 49°, this shows an increment of 2½°—nearly corresponding with the difference due to latitude. But the real difference is not this. It arises from the very much smaller range in the small island. Thus the mean autumn temperature is four degrees, and the winter six degrees higher than at Greenwich, while the spring is only one degree warmer, and the summer half a degree cooler. The months show this more clearly; for December and January are each seven degrees warmer, and May and June one degree cooler. On the whole, the spring in Guernsey is a little warmer, and the summer rather cooler, than at Greenwich, while the temperature of July and August continues, with little change, into September and October. Winter is therefore absent as a season, but spring is cold and late.

The daily range of the thermometer is also very small. At Greenwich, on an average of ten years, it was 16·2°; and for the same years in Guernsey exactly half, or 8·1°. The following tabular statement of the mean daily range of each month will, however, be the best illustration of this:—

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[*] The account from which this memoir was prepared has since been published. It will be found in 'The Channel Islands,' by Prof. Ansted and Dr. R. G. Latham, 1 vol. 8vo. London 1862.

	Greenwich.	Guernsey.		Greenwich.	Guernsey.
April	19·1°	9·3°	October	14·6°	6·7°
May	20·2	10·5	November	11·7	6·1
June	20·8	11·6	December	9·5	6·2
July	21·3	10·7	January	10·0	6·4
August	20·0	10·0	February	12·3	7·1
September	19·8	8·5	March	15·2	7·8

The difference thus indicated is total, and is connected with another, also very important, namely the total absence of night frosts in Guernsey. The effects on vegetation are very remarkable.

The extremes of temperature in Guernsey also range within narrow limits. There has been no reading of an accurate thermometer recorded higher than 83°, or below 24·5°.

2. *Barometric pressure.*—The fluctuations of the barometer in Guernsey are frequent, but moderate. The maximum height of the column is in September and December, and the minimum in October and April; and, as in England, the pressure is generally greater in summer than in winter.

3. *Winds.*—The absolute force of the wind does not seem to be excessive, though squalls are frequent and violent. North-west winds blow, on an average, 109½ days, north-east winds 107, south-west 100, and south-east 50. North-east winds prevail in September, May, and March, the average being 12½, 12½, and 11½ days. North-west winds preponderate in August; and in April north-east and north-west winds are equal. In no month is there an average of more than 6½ days of south-east wind. During June, July, August, October, and January, nearly two-thirds of the weather is from westerly quarters; and during March, May, and September, from easterly quarters.

4. *Rain-fall.*—The mean annual rain-fall in Guernsey is nearly 35 inches, falling on 164 days. October is the wettest month, and January the month in which the number of rainy days is greatest. From May to August, inclusive, are the driest months, the total rain-fall being 8¼ inches; and from October to January the wettest, when 16½ inches fall. More rain falls in the night than during the day. A continuance of twelve hours' rain is rare, and the finest days often succeed the worst mornings. Snow rarely falls, and when it does, is generally with a south-east wind late in the season. Hail occurs at all seasons, but not often very heavily.

5. *Cloud and Moisture.*—The air is very frequently clouded in Guernsey, but only partially. The mean cloudiness of the year is about 5½, a completely clouded sky being 10. The air is seldom saturated with moisture, though the mean humidity is ·854. The extreme of humidity is in February, when the temperature is lowest. The driest month is August, when the temperature is highest. Dense sea-fogs are common in May and June; but the total number of days of thick weather in the year is not large. The dews are very heavy.

6. *Ozone.*—The ozone-observations range over too short a period to be of much value, but the means during that period were not high, especially during the summer months. September to January, inclusive, were the months of maximum ozone.

JERSEY.

The climate of Jersey differs from that of Guernsey much more than would be expected from its close vicinity and similarity of form, elevation, and soil. The mean temperature is nearly the same, Jersey being 0·3° higher; but the spring, summer, and autumn are warmer than the mean, and the winter colder. Thus from April to October, inclusive, the mean of Jersey is one degree higher than in Guernsey; and from November to January, inclusive, three-quarters of a degree lower. During the other months the means correspond. The daily range differs considerably. Thus in December it is 17·7° in Jersey, and in Guernsey only 7°; in January the figures are 7·1° and 6·7°, and in July 6·8° and 6°. August alone shows a small difference the other way, the range then being somewhat greater in Guernsey, and the mean temperature more than one degree lower.

Elements of the Climate of Guernsey.—Mean Results of Observations extending over sixteen years, from January 1st, 1843, to December 31st, 1858. By S. Elliott Hoskins, M.D., F.R.S. [Latitude of Station, 49° 27½′ N. Longitude, 2° 32′ W. Height of Station above mean sea-level, 204 feet.]

Observations.	Jan.	Feb.	March	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean of 12 Months.	Means of Seasons.			
														March. April. May. Spring.	June. July. August. Summer	Sept. Oct. Nov. Autumn	Dec. Jan. Feb. Winter.
Barom. corrected and reduced to 32°	29·811	29·852	29·851	29·771	29·813	29·872	29·882	29·818	29·896	29·762	29·817	29·905	29·838	29·812	29·857	29·825	29·860
Elastic force of vapour	·272	·254	·256	·230	·334	·403	·452	·447	·433	·363	·306	·274	·334	·273	·433	·367	·264
Pressure of dry air	29·549	29·598	29·595	29·541	29·479	29·469	29·422	29·371	29·463	29·399	29·511	28·631	29·504	29·539	29·424	29·458	29·596
Range of barometric readings	1·316	1·096	1·225	·980	·911	·760	·706	·701	·993	1·218	1·212	1·220	1·028	1·035	·722	1·141	1·219
Meantemp. of air corrected	43·6	42·5	43·5	47·4	52·	57·8	61·	61·1	58·8	54·	48·7	46·5	51·6	47·7	59·9	53·8	44·2
Mean temp. of dew-point	39·3	37·9	38·8	42·4	46·	51·6	55·1	54·6	53·6	49·2	43·7	40·7	46·1	42·4	53·8	48·8	39·4
Mean dryness—thermometric scale	4·3	4·5	4·5	5·	6·	6·2	5·9	6·5	5·2	4·8	5·	5·8	5·5	5·3	6·1	5·	4·8
Mean humidity—hygrometric scale	·866	·877	·859	·857	·836	·861	·848	·827	·868	·850	·852	·847	·854	·851	·845	·857	·862
Highest readings of max. thermometer	54·5	56·	61·5	66·	73·	80·	83·5	79·	76·	70·5	62·	50·	83·5	73·	83·5	76·	59·
Lowest readings of min. thermometer	24·5	27·	27·	34·	39·	44·	50·	50·5	48·	41·	30·5	29·	24·5	27·	44·	30·5	24·5
Mean monthly range of temperature	20·5	19·6	21·8	22·6	24·8	25·4	22·2	20·3	20·1	20·4	19·7	20·1	21·4	23·1	22·6	20·1	19·9
Mean daily range of temp.	6·4	7·1	7·8	9·3	10·5	11·6	10·7	10·	8·5	6·7	6·1	6·2	8·1	9·2	10·8	7·1	6·7
Amount of rain collected	3·844	2·362	2·238	2·513	2·231	2·100	2·339	2·032	2·711	5·082	3·788	3·526	34·766	6·982	6·471	11·581	9·705
Number of days of rain, hail, or snow	18·3	13·6	13·5	13·4	10·5	10·	10·8	10·8	11·2	18·	16·8	17·5	164·5	37·4	31·6	46·2	49·3
Mean amount of cloud	6·2	5·6	5·	4·6	5·	4·8	4·7	5·6	4·5	6·1	6·	6·1	5·4	4·9	5·	5·5	5·9
Force of wind, by estimation	1·8	1·6	1·7	1·6	1·6	1·5	1·4	1·5	1·7	1·7	1·7	1·7	1·6	1·7	1·5	1·7	1·7
Number of days on which the wind blew from N.E.	6·3	8·3	11·6	10·3	12·4	9·4	7·1	7·4	12·6	6·8	7·5	7·5	107·2	34·3	23·9	26·9	21·7
N.W.	9·8	8·4	8·	9·2	7·9	8·6	10·4	2·5	7·4	9·	9·7	8·7	109·6	25·1	31·5	26·1	25·0
S.E.	[illegible]	[illegible]	4·7	[illegible]	[illegible]	[illegible]	[illegible]	4·7	[illegible]	4·5	[illegible]	5·7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The general result shows a greater variability in the climate of Jersey. The daily range during six years of mutual good observation was 11·6° in Jersey and 8° in Guernsey, and the mean monthly range 27·9° and 20·6° respectively. All these particulars of climate are further illustrated by a careful comparison of tabulated results.

The barometric pressure in Jersey generally varies less than in Guernsey; and the two islands by no means correspond in range or actual pressure. They occupy different positions with regard to the great atmospheric wave.

Jersey is less cloudy than Guernsey; the number of days of rain-fall is smaller, and the quantity of rain is also smaller. The two islands are exceedingly different in respect to humidity, both in amount and season. The monthly range of humidity is greatest in Jersey.

On the whole, Jersey is drier and warmer than Guernsey, and has a clearer atmosphere; it is hotter in summer and cooler in winter. The pressure of the air varies less frequently, but within larger limits; heavier rain falls there, but more rain falls in the year, and it falls on more days, in Guernsey.

The climates of Alderney and Sark have not been carefully observed. It is generally considered that both are more bracing than the larger islands.

All the Channel Islands agree in some general conditions of the climate. A general summary of these will be useful.

The equability and duration of autumn are, in ordinary seasons, extremely remarkable. Storms, and occasional heavy rains, usher in this season; but they are not succeeded by cold. In the intervals, up to the end of the year, the weather is remarkably fine and genial, with no night frosts. From the 10th October to the end of the month is what is called St. Martin's summer, and the weather is then singularly agreeable. The same kind of weather often recurs in the middle of December.

During the spring months, east, north-east, and north winds, and sometimes north-west winds, are frequent and violent, and often extremely disagreeable. They feel cold, but do not bring down the thermometer. They are often very dry. The night temperature is still comparatively high, hoar frost being rarely seen, except in exposed, bleak, and high positions, and in the months of January and February. February is the coldest month of the year.

The days in summer are rarely hot; the nights are cool and pleasant, almost without exception. The latter part of summer is generally fine and pleasant, passing into early autumn without perceptible change.

A Journey to Harran in Padan-Aram and thence over Mount Gilead into the Promised Land. *By* Charles T. Beke, *Ph.D., F.S.A., F.R.G.S., &c.*[*]

Towards the close of the year 1861, Dr. Beke, accompanied by his wife, undertook a journey to Harran, the residence of the Patriarch Terah and his descendants, and thence over Mount Gilead into the Promised Land, by the road taken by the Patriarch Jacob in his flight from his father-in-law Laban.

Harran is a village situate at the eastern extremity of the *Ghuthah* or Plain of Damascus, which Dr. Beke identifies with the Land of Uz (*Hûtz*) of the Book of Job[†]. It is usually distinguished as *Harran-el-Awamid*, or Harran of the Columns, from three Ionic columns, which, with numerous other remains, prove that in the intervening ages there was here a Greek or Roman city. The name of this city is lost, Harran having resumed its Scriptural appellation before the twelfth century, when it was described by the Arabian geographer Yakut as "one of the towns of the Ghuthah of Damascus."

At the entrance from the west is a draw-well of great antiquity, which Dr. Beke identifies with the well at which Abraham's steward, Eliezer of Damascus, met Rebekah. Some of the water has been analysed at the Royal School of Mines, by direction of Sir Roderick I. Murchison, and found to contain 109·76 grains of solid matter in the gallon. The water of a second well near the former is so impure as to be no longer fit for use, and at the present day the inhabitants obtain their chief supply of water through an artificial canal.

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[*] See also Journal of the Royal Geographical Society, vol. xxxii. pp. 76–100.

[†] See 'Origines Biblicæ,' pp. 137–153.

On the first day of the present year (1862), the travellers left Harran on their way to Mount Gilead. They first came to the river Awaj, the ancient Pharpar, forming with the Barada—the Abana of Scripture—the two "Rivers of Damascus," the capital of Aram or Syria; which rivers gave to *Aram Naharaim*, or "Aram of the Two Rivers," its distinguishing appellation. This district, though not incorrectly called "Mesopotamia of Syria," has been supposed to be the *Mesopotamia of Assyria*, between the two rivers Euphrates and Tigris, whence have arisen considerable errors in Scripture geography and history.

When, according to the Scripture narrative, Laban set "three days' journey" between his flocks and those of his son-in-law Jacob, it is reasonable to infer that the latter led his flocks in the direction best adapted for his contemplated flight from Padan-Aram; that is to say, up the left bank of the Awaj. The spot where he crossed the river would consequently have been at or near Kiswe, a town on the great pilgrim-road between Damascus and Mekka; and thence he would have proceeded south over the plains of Harran. This is the road taken by Dr. Beke; and certainly nothing could so graphically describe it as the few simple words of Scripture:—"He passed over the river, and set his face toward the Mount Gilead." A traveller, however much unacquainted with the country, has only to proceed along the high road, running straight from north to south over an almost level plain, without a mountain intervening to lead him astray, and he soon sees before him the summit of Gilead, standing out separately and distinctly, and towards it he "sets his face."

The distance travelled by Jacob before Laban "overtook him in the Mount Gilead" is stated to have been "seven days' journey." Travelling much quicker than the patriarch could have done, it was on their fifth day from Harran that Dr. and Mrs. Beke ascended the side of Gilead, where they soon came to some delicious springs of water in the midst of luxuriant pasturage. At such a spot the Patriarch Jacob, with his wearied flocks and herds, would naturally have stopped and pitched his "tent in the mount," where he was overtaken by Laban. A few minutes more brought the travellers to the summit of Gilead, where they enjoyed an extensive view over the Promised Land, embracing Mount Tabor, Nazareth, Cana, Tiberias, and other places rendered ever memorable by Our Lord's ministry and miracles. After the reconciliation between Laban and Jacob, it is said that "Jacob went on his way, and the angels of God met him, ... and he called the name of the place Mahanaim." Close to where Dr. Beke crossed the summit of Gilead is a ruin called Mahneh, which may be looked on as representing the spot where the patriarch, on his first coming within sight of his native country after an absence of twenty years, was favoured with this manifestation of the Divine presence.

Shortly after leaving the pass of the mountain, Dr. and Mrs. Beke came to a *cromlech*, in form and appearance almost identical with Kits-Coty House, in Kent. Thence proceeding down Wady Ajlun, and then crossing Wady Rajib, they reached the *Ghor*, or plain of the Jordan, not far to the north of Wady Zerka, the river Jabbok of Scripture, over which the Patriarch Jacob crossed before meeting his brother Esau, and where "there wrestled a man with him until the breaking of the day; . . . . and Jacob called the name of the place Peniel."

After his meeting with his brother, Jacob, professing to accompany him, journeyed to Succoth, "leading on softly," and there stopped to "build him an house, and make booths for his cattle;" whilst "Esau returned that day on his way unto Seir." Succoth has been supposed to be on the west side of Jordan, a few miles to the north of the Jabbok; but the whole context shows that the patriarch, in order to get free from his brother, pretended to be going on with him towards Seir, but stopped all at once, as if weary, at Succoth, whilst Esau unsuspectingly continued his journey. Succoth is accordingly placed by Dr. Beke at a short distance to the south of the Jabbok, on the east side of Jordan. Crossing here the river, the patriarch would, on the opposite side, have entered the mouth of Wady Fār'a, where it joins the Jordan from the north-west, and continuing up the valley, he at length "came to Shalem, a city of Shechem, which is in the land of Canaan, when he came from Padan-Aram, and pitched his tent before the city."

Dr. and Mrs. Beke, being unable to obtain an escort to accompany them as far south as the Jabbok, crossed the Jordan at the point where they first reached it. While proceeding along the opposite bank, they were attacked by a party of Beduins; after freeing themselves from whom, they at once crossed the mountains between the Ghor and Wady Far'a, where they again fell into the road taken by the Patriarch Jacob, along which they continued to Nablûs, the ancient Shechem, arriving there on the tenth day after their departure from Harran.

On the Geography of Mont Pelvoux, in Dauphiné.

By the Rev. T. G. Bonney, *M.A., F.G.S.*

This district of the Alps is very imperfectly laid down on all the maps at present published. The following are the principal authorities known to me:—(1.) A map by General Bourcet, published at Paris in the year 1758. It is a most laborious performance, and very accurate for all parts below the snow-line, but above that of little use. (2.) A paper by M. Elie de Beaumont, in the 'Annales des Mines,' 3me Série, tome v. In this there is some very valuable information, but given in so confused a manner, that it requires a thorough knowledge of the district to understand it. (3.) A most interesting article on Dauphiné, by Professor Forbes, at the end of his work on Norway and its Glaciers (published 1853). He did not, however, pierce the "massif" of the Pelvoux, and consequently, being misled by Bourcet's map, he speaks of it as a single mountain, overhanging the valley of La Berarde. (4.) A paper by Mr. Whymper, in the second volume of the second series of 'Peaks, Passes, and Glaciers' (published in 1862). This gentleman ascended, for the first time on record, the highest peak of the Pelvoux, but misunderstanding Elie de Beaumont, he has fallen into several topographical errors. The Pelvoux was also ascended during the past summer by Mr. Tuckett, of Bristol, who was the first person to clear up the difficulties about the heights and names of the mountain. On his return through Paris, he saw at the Département de la Guerre the manuscript map made from Capt. Durand's survey in 1828. He obtained a tracing of the district in the immediate neighbourhood of the Pelvoux, of which he has kindly sent the author a copy. It is impossible to speak in too high terms of commendation of this map, but unfortunately it will not (as he was informed at the Department) be published for five years. The chief features of the district are as follows. The watershed between the Romanche and the Durance, after passing the Col du Lautaret and running south for some four miles, turns to the south-west for about three miles, and then turns to the south again, passing through the Pointe des Ecrins (the highest mountain in the group), 13,462 feet, and l'Aléfroide, 12,878 feet. Where the line turns to the south, a large offshoot runs in a north-westerly direction, in which are the Aiguille du Midi de la Grave, 13,081 feet, and the great Glacier du Mont de Lans. From the Pointe des Ecrins a short spur runs out to the east, dividing the Glaciers Blanc and Noir. From the Aléfroide another large spur runs out to the east, terminating in the Grand Pelvoux, 12,973 feet. This portion of the chain may be said to consist of four distinct peaks—(1) l'Aléfroide, two rocky aiguilles without name, 11,772 feet? and 12,845 feet? respectively, and the Grand Pelvoux, with its five heads. Besides these there are several other mountains in the district, from 11,000 to a little over 12,000 feet. The authority for the heights is a list obtained by Mr. Tuckett from the Etat-Major Français. The scenery of this part of Dauphiné is of the grandest description; some of the snow-fields and glaciers are of great extent, and the magnificent precipices that surround them equal, if they do not surpass, anything that can be found in Switzerland or Savoy.

On Colour as a Test of the Races of Man. By J. Crawfurd, *F.R.S.*

Colour in different races appeared to be a character imprinted upon them from the beginning, because, as far as our experience goes, neither time, climate, nor locality has produced any change. Egyptian paintings 4000 years old represent the people as they are now. The Parsees in India who went from Persia are now the same as when they migrated a thousand years ago. African negroes that have for three centuries been transported to the New World remain unchanged. The Spaniards settled in tropical America remain as fair as the people of Arragon and Andalusia. He contended that climate had no influence in determining colour in different races. Fins and Laps, though further north, are darker than the Swedes; and within the Arctic circle we find Esquimaux of the same colour and complexion as the Malays under the Equator. Yellow Hottentots and Bushmen live in the immediate neighbourhood of Black Caffres and negroes. There is as wide a difference between the colour of an African negro and a European, between a Hindu and a Chinese, and between an Australian and a Red American, as there is between the species of wolves, jackals, and foxes. The arguments for the unity of the human race drawn from anatomical reasoning would also prove that there was no difference between hogs and bears, the bovine and equine and the canine families.

On Language as a Test of the Races of Man. *By* J. Crawfurd, *F.R.S.*

The author commenced by observing that on former occasions he had referred to the subject of this paper, but now he did not hesitate at once to affirm that language, though yielding valuable evidence of the history and migrations of man, affords no sure test of the race he belongs to. In illustration he said that the majority of the people of this country, who 2000 years ago spoke their own native tongues, whatever those might have been, now spoke a language derived from Germany, on which has been engrafted a considerable portion of one which had its origin in Italy, while of their native tongues two examples only remained, and these, without doubt, were doomed in a few generations to extinction as living languages. France, Egypt, Northern India, the New World, and other regions, also exhibited cogent illustrations of a similar character, one of the most important being the fact, well ascertained, that, so wonderful is the flexibility and compass of the human organs, the children of races the most opposite, when duly taught from infancy, will acquire a complete mastery over any foreign languages, be they ever so difficult of pronunciation or complex in structure.

Some Observations on the Psychological Differences which exist among the Typical Races of Man. *By* Robert Dunn, *F.R.C.S. Engl.*

The object of the author in this paper was to indicate and suggest to the psychological and ethnological Members of the British Association a field of investigation and inquiry, which, in his estimation, if thoroughly explored, could not fail, unless he was greatly mistaken, of yielding a rich harvest, and of throwing a flood of light upon the causes of the psychological differences which exist among the typical races of man. He maintains that the Genus *Homo* is one, and that all the races of the great family of man are endowed with the same instinctive intuitions, sensational, perceptive, and intellectual, the same mental activities,—in other words, that they all have as constituent elements the germs or original principles *in common*, of a moral, religious, and intellectual nature, so that, however great and striking their psychological differences may be, they are nevertheless differences in *degree, and not of kind.*

Viewing the brain or encephalon as the material organ of the mind, where the ultimate molecular changes precede the mental states, and from whence the mandates of the will issue, whether for the production of voluntary motion or for other acts of volition, he dwells on the paramount importance of assiduously studying and carefully comparing and contrasting, the cerebral developments of the different races, with a view, and as the most efficient means, to the better understanding and elucidation of the psychological differences which exist among and characterize them. But the cerebral physiology of the typical races remains to be wrought out, and ethno-psychology is still a desideratum. Significant among them as the varying forms of the skull may be, and important as is the division of the whole human family, by Retzius, into Dolichocephalic and Brachycephalic, with its sub-division, according to the *upright* or *projecting* character of the jaws, into *orthognathous* and *prognathous*, and as characterizing and indicating *elevation* and *degradation of type*, the author considers that the time has come not to be satisfied with a mere external survey, but that the bony coverings should be removed, and, under the guidance of the chart provided by the indefatigable Gratiolet, the cerebral convolutions themselves should be thoroughly examined, and carefully compared and contrasted with each other, in all the typical races. When this has been done, but not until then, shall we, in his opinion, have a clue likely to unravel and elucidate many of the existing obscurities appertaining to their psychological differences. Much as it is to be regretted that the brains of the lowest and most degraded of the human races have been so little examined, it is now to be hoped that, in respect to the aboriginal tribes at the Cape of Good Hope, in Australia, and, within reach, the Hill Men of India, as well as elsewhere, medical men will be found to supply this desideratum of ethno-psychology. This accomplished, he thinks we shall cease to wonder how it happens that the North American Indians, on the very confines of civilization, should remain uncivilized—the same wandering lawless savages which they were when Columbus first set his foot among them; how their wigwams and the miserable bark huts of the aborigines of New Holland should have been swept away before the flood-tide of European civilization—those homeless savages themselves seeking refuge in the desert and the mountain; and, again, among the Mongolian nations of Asia, that we shall be better enabled to comprehend how it is that their civilization, so early attained, has not progressed, but remained stationary: China, boasting of a civilization nearly as old as that of Egypt, has remained stationary for thirty centuries. Lastly, even among the European nations, the distinctive characters of the Saxon and the Celt, he is inclined to believe, will be found to be engraven on their brains.

As instances from savage life, he views, in contrast, the African Negro and the North American Indian, with the intent of showing, so far as the subject has hitherto been investigated, what light the differences in their cerebral developments can throw on their respective characters, mental manifestations, and destinies. Among the Negro tribes there is a great variety, and much difference in their mental endowments. Some have become excellent mechanics, others clerks and accountants, while others have remained mere labourers, incapable of any intellectual attainments, and characterized by low and receding foreheads. When free from pain and hunger, the life of the Negro is one of enjoyment. As soon as his toils are for a moment suspended, he sings, he seizes his fiddle, he dances. Easily excitable, and in the highest degree susceptible of all the passions, he is more especially so of those of the mild and gentle affections. The American Indians, on the contrary, are averse to civilization, and slow in acquiring knowledge. They are restless, stern, silent, and moody, and to them a ruminating life is a burden. They are revengeful, wild, vindictive, cunning, but wholly destitute of maritime adventure; too dangerous to be trusted by the white man in social intercourse, and too obtuse and intractable to be worth coercing into servitude.

The Negro is *Dolichocephalic*, the Indian *Brachycephalic*, and both are *prognathous*. Their cranial and cerebral differences are striking. The skull of the Negro is long, but narrow, and the forehead low, but it rises higher, and is more developed in the intellectual and moral regions, than that of the Indian; the occiput is large. In the Red Indian the skull is small, and short from front to back; it is wide between the parietal protuberances, prominent at the vertex, and flat at the occiput; its great deficiency lies in the superior and lateral parts of the forehead. The anterior lobe of the brain in the Negro and Indian is small, while in the European it is large, in proportion to the middle lobe. The posterior lobe of the Indian is small, but the vertex of the middle lobe is prominent, and the brain is wide between the parietal protuberances. In the Negro the posterior lobe is more fully developed, but it is in the European brain that it reaches its maximum development. Both in the Negro and Indian the cerebral hemispheres are pointed and narrow in front, and their transverse convolutions in the frontal lobes are markedly conspicuous for the simplicity and regularity of their arrangement, and for the perfect symmetry which they exhibit in both of the hemispheres, when compared and contrasted with the complexity and irregularity which are presented in the brain of the European. Such differences as these, the author considered, warrant the inference that, alike in the Negro and the Indian, the nervous apparatus of the perceptive and intellectual consciousness falls far short of that fulness, elaboration, and complexity of development which characterize the Caucasian brain; and hence the reason why the large-brained European differs from and so far surpasses the small-brained savage in the complexity of his manifestations, both intellectual and moral. In conclusion, he observed that the leading characters of the various races of mankind have been maintained to be simply representatives of a particular type in the development of the highest or Caucasian; the Negro exhibiting permanently the imperfect brow, projecting lower jaw, and slender bent limbs of the Caucasian child some considerable time before its birth, the aboriginal Americans representing the same child nearer birth, and the Mongolian the same newly born.

Exploration dans l'Afrique centrale, de Serre-Leone à Alger, par Timbuctoo.

By JULES GÉRARD.

On leaving Sierra Leone, the author proposed to visit the source of the Niger, and also to visit the Republic of Liberia. He should then make for the Kong Mountains, between which district and Timbuctoo a different race of natives was found. He did not propose to travel with a caravan, but with the tribes of the district. At Timbuctoo, or Ain Saleh, he hoped to discover the papers and journals of Major Laing, the African traveller, who was assassinated near Timbuctoo. The author expressed a confident belief that these papers were still in existence, since the natives of the interior had almost a superstitious veneration for written characters, and treasured the most worthless scraps until long after they were illegible. His route would be through a country possessing a double interest, both geographical and ethnological. The journey was long and perilous; but he had weighed the difficulties of the route, and confidently expected to make his way from Sierra Leone to Algeria in safety.

A Letter from DR. LIVINGSTONE, *communicated by* Sir Roderick Murchison.

"Shupanga, River Zambesi, April 29, 1862.

"My dear Sir Roderick Murchison,—With a sore, sore heart I must tell you of the loss of my much-loved wife, whose form was laid in the grave yesterday morning. She died in Shupanga-house on the evening of the 27th, after about seven days' illness. I must confess that this heavy stroke quite takes the heart out of me. Everything else that has happened only made me more determined to overcome; but with this sad stroke I feel crushed and void of strength. Only three short months of her society after four years' separation! I married her from love, and the longer I lived with her I loved her the more. A good wife, and a good, kind, brave-hearted mother was she, and deserved all the praises you bestowed on her at our parting dinner, for teaching her own, and the native children too, at Kolobeng. I try to bow to the blow as from our Heavenly Father, who orders all things for us. Some may afford to be stoical, but I should not be natural if I did not shed many tears over one who so deserved them. I never contemplated exposing her in the lowlands. I proposed that the Nyassa steamer should sail out, and on reaching Kongone cut wood and steam up the river. This involved but a few days in the lowlands; but another plan was preferred. She (*i. e.* the steamer) came in pieces in a brig. Gladly accepting the kind offer of Captain Wilson, of Her Majesty's ship 'Gorgon,' to help us up to the Murchison cataracts, we found after a month's trial that the state in which the engines were precluded ascending the Shire with the pieces on board the 'Pioneer.' We were forced to put her together at Shupanga, and we have been three months, instead of three or four days, detained here. Had my plan been adhered to—but why express useless regrets? All has been done with the best intentions. But you must remember how I *hastened* the first party away from the Delta, and though I saved them, got abused for breaking the Sabbath. Then I prevented Bishop Mackenzie's party landing at all, till these same unhealthy months were past, and no one perished until the bishop came down to the unhealthy lowlands and died. The Portuguese have taken advantage of the sanitary knowledge we have acquired, and send their *teté* at once. They lost but two of a detachment, while formerly, by keeping them at Quillimane and Sena, nearly all were cut off.

"I shall do my duty still, but it is with a darkened horizon I set about it. Mr.

Rae put the hull of the new steamer together in about a fortnight after we brought up the keel. She looks beautiful and strong, and I have no doubt will answer all our expectations when we get her on the lake.

"Ever affectionately yours,
"DAVID LIVINGSTONE."

On Serious Inaccuracies in the Great Survey of the Alps, south of Mont Blanc, as issued by the Government of Sardinia. By W. MATHEWS, Jun., *M.A., F.G.S.*

The maps referred to were the six-sheet map of Savoy and Piedmont which appeared in 1841, the great ninety-one-sheet map now in course of publication, and that attached to the work entitled 'Le Alpi che cingono l'Italia,' dated 1845, all of which were issued by the War Department of the Sardinian Government. Among the many cases of error, the most extraordinary was that of the Mont Iséran, a mountain stated to be nearly 13,300 feet high, hitherto supposed to be the culminating peak of the Graian Alps, and represented as situated in Savoy, immediately on the east of the Col of the same name. From investigations made in the country by Mr. Mathews and other travellers since the year 1859, it was now conclusively established that no such peak exists in the situation in which it is placed by the Sardinian engineers. The height of the so-called Mont Iséran was determined trigonometrically at the commencement of the present century by Colonel Corabœuf, of the Etat-Major Français, and on referring to his original memoir, it appears that the peak he measured is situated in Italy, and is, in fact, the Grand Paradis, a mountain nearly fifteen miles distant from the supposed site of the Mont Iséran. Mr. Mathews next described the position of the eight principal summits of the Graian Alps, rising above 12,000 feet, most of which had been ascended for the first time, and their altitudes determined, by members of the Alpine Club within the last three years. He showed that these mountains were most incorrectly represented on the maps, and stated his conviction that the main Alpine ranges had been roughly drawn in the office of the War Department and never properly surveyed.

Decipherment of the Phœnician Inscription on the Newton Stone, Aberdeenshire. By the Rev. Dr. MILL.

The subject of this paper was an inscribed stone, found at a village in Aberdeenshire, some miles from the coast, and in a country containing many of what are commonly called Druidical monuments. Dr. Mill read the inscription backwards, decided that the letters were Phœnician, and explained them by the corresponding letters of the Hebrew alphabet. According to his interpretation, it was a votive monument dedicated to Eshmûn, god of health (the Tyrian Esculapius), in gratitude for favours received during "the wandering exile of me thy servant,"—the dedicator being "Han-Thanit-Zenaniah, magistrate, who is saturated with sorrow." Dr. Mill discussed the question whether Han-Thanit-Zenaniah had suffered from disease or shipwreck, and whether his sorrow had been caused by the loss of companions, or friends, or relations. He discussed also the peculiarity of the word used in the signification of magistrate, and pointed out that he appeared to have been a man of consular dignity who had commanded a ship or fleet which came to Britain, and that this and other circumstances pointed to the earlier period of the history of Tyre.

On Recent Notices of the Rechabites. By Signor PIEROTTI.

Towards the end of April 1860, the author, travelling south of the Dead Sea, and in a valley about two miles therefrom, met a tribe of Rechabites, whose object was to procure a supply of linen and salt; the next day another tribe arrived, on a similar errand; these all described themselves as descendants of Ishmael—a mistake of course if they were really Rechabites, which they also claimed to be. They were exceedingly clean in their dresses and persons—cleaner than any other Bedouins; but the most singular point connected with them was that they had a copy of the Scriptures in Hebrew. With regard to their being descendants of Rechab, they quoted Jeremiah xxxv. 4–7. They stated themselves to be 600,000 in number, thus confirming the prophecy, and the chief location of the tribes to be the south-east of the Mountains of Moab. Their general sojourn is on the west shore of the Dead Sea, and some of their members had been heard to say prayers at the tomb of a Jewish rabbi, in the Hebrew language. A rabbi named Gadd fell into their hands, and was robbed of everything, but bewailing his loss in the words commencing "Hear, O Israel, the Lord our God is one God," and being overheard, the tribe who had robbed him returned him all the spoil. He endeavoured to induce them to part with a copy of their Scriptures, which he actually saw, but they said that money was of no consequence to them, and that the books were very expensive in transcription.

On Terrestrial Planispheres. By the Chevalier IGNAZIO VILLA.

On the Trade of the Eastern Archipelago with New Guinea and its Islands.

By ALFRED R. WALLACE, *F.R.G.S., F.Z.S.*

The part of New Guinea with which trade is regularly maintained extends from the eastern extremity of the great Geelvink Bay, in about long. 137° E., to very nearly the same longitude on the south coast, a little beyond the river Utanata. This is a coast-line of more than 1200 miles, and it embraces also the islands of Jobie, of Biak and Sook, Waigiou, Salwatty, Batanta, Mysol, and the Ké and Aru Islands, all of which are inhabited by branches of the Papuan race.

From the interior parts of New Guinea the only articles of commercial importance are aromatic barks and wild nutmegs. From the coasts and islands, tripang or bèche-de-mer, pearl-shell, and tortoiseshell are all obtained in abundance, and form the most valuable portion of the trade. Less in quantity and importance are pearls, sago (raw and in cakes), birds of paradise, mats, palm-leaf boxes, and rice in the husk (paddy). These articles are mostly consumed in the East, some (as the aromatic Mussoi bark) in Java, others (the tripang and pearls) in China, the pearl-shell being the only article the whole of which finds its way to Europe.

The trade is almost entirely carried on by native prahus from Celebes and the Moluccas—rude vessels, sometimes built entirely without iron, carrying mat-sails on a triangular mast, and altogether incapable of beating against the wind. They therefore make but one voyage a year, going at the beginning of the west monsoon in December and January, and returning with the east monsoon in July and August. The trade is entirely carried on by barter,—calicoes, red cotton, bar-iron, chopping axes, cheap German knives, Chinese crockery, brass wire, coloured beads, silver coins, tobacco, arrack, and opium being the articles chiefly in demand by the natives, some being required in one district, while a different assortment is required in another. In some parts, as at Dorey, Mysol, and Aru Islands, trade is carried on with peace and regularity; in others, as Jobie and the neighbourhood of Macluer Inlet, bargains are made by both parties fully armed and ready, should the negotiations not prove satisfactory, to settle the matter by a deadly combat. In these parts scarcely a year passes but some traders are killed either in open combat or by hidden treachery, and whole crews are often massacred.

To give some idea of the extent of this trade, I may mention that when I visited the Aru Islands in 1857, there were 15 large prahus from Macassar, besides about 100 small ones from various other islands, and I estimated the value of the produce which they took away at about £20,000.

Sago is the staff of life in these countries, and the chief support of all engaged in the New Guinea trade. To see sago manufactured by the natives is an extraordinary sight. A whole tree-trunk, about 20 feet long and 5 feet in circumference, is by a few days' labour, converted into human food. A good-sized tree will produce 30 bundles of raw sago, weighing about 30 lbs. each bundle, and when baked yielding about 60 cakes of 3 to a pound. Two of these cakes are a meal for a man, or about 5 cakes per day; and as a tree produces 1800 cakes, it gives food for one man for about a year. The labour to produce the raw sago, by breaking up and washing the pithy substance of the trunk, is about 10 days for one man, which labour provides him with food for a year. This great cheapness of food leads to excessive laziness and misery. There is no stimulus to labour, and we find that the sago-eaters have generally the most miserable of huts and the scantiest of clothing. In the western islands of the Archipelago, where rice is the common food, and some regular labour and foresight are required to produce it, the populations are in general more wealthy, more industrious, and more intelligent, and there is much more likelihood of introducing among them the rudiments of knowledge and civilization.

The more detailed information given in the paper of which this is an abstract was collected by myself during three voyages to various parts of the coasts and islands of New Guinea, in the years 1857, 1858, and 1860, mostly undertaken in native prahus, and with a view to the investigation of the natural history of the country.

On the Human Remains found in the course of the Excavations at Wroxeter.

By Thomas Wright, *F.S.A.*

Mr. Wright stated that human remains had been found in the excavations at Uriconium under three different classes of circumstances:—First were the ancient Roman cemeteries outside the town, which had been partially explored last autumn, and which were now under a course of further exploration. In an ethnological point of view the discoveries here were of comparatively little use, because, as all the interments hitherto discovered were by cremation, no skulls or other perfect bones were found among the remains of the dead; but we derived from them the knowledge of the important fact that the inhabitants of Uriconium continued to burn their dead, and, in fact, seem to have had no other mode of burial, until the latest period of the existence of the city, that is, after the Roman government had been withdrawn from the island. Secondly, there were the remains of the inhabitants of the town, men, women, and children, who had been massacred by the savage barbarians when the city was taken and destroyed. He told several interesting anecdotes of the circumstances under which these remains had been found; and he stated that the skulls of these people presented no peculiarities which might not be found in any civilized town, such as Uriconium undoubtedly was. In the third place came the deformed skulls which had been the subject of so much discussion, a discussion which seemed not yet to have led to any satisfactory result. He described the circumstances and conditions under which these skulls had been found, and stated reasons for suspecting that the interments belonged to a considerably later date than had been supposed. His friend Dr. Henry Johnson, of Shrewsbury, in a very able paper recently read before the Royal Society, had undertaken to show that there are chemical elements in the earth in which these remains lay which might have so far affected the substance of the bone as to render it pliable and capable of becoming deformed after death. But, supposing this to be the case, we seem to want entirely the mechanical cause of deformation. The bodies were not buried sufficiently deep to have a weight of earth upon them; in fact, when buried, their graves must have been very shallow. No weight of buildings or of ruins had been laid upon them; but, on the contrary, from the quantity of small fibres of roots which are mixed with the earth, it appeared probable that during the middle ages the spot had been covered with low brushwood, which was usually the case with deserted ruins. He suggested that we can hardly understand why such a cause, affecting bones in this field, should not equally affect the skulls of the bodies interred in the adjacent churchyard; or why all the deformed skulls in this field should have the same deformity, or why the other bones of the body should not be similarly affected. The skulls of the Roman inhabitants, found with a great weight of ruins upon them, have in no instance yet observed undergone any similar deformity; and it must be added that the few skulls not deformed, found among these deformed skulls, were comparatively good types. It is intended to have a fresh and more careful exploration of the ground, in the hope that thereby some further light may be thrown on the subject.

STATISTICAL SCIENCE.

On the Progress of Instruction in Elementary Science among the Industrial Classes under the Science Minutes of the Department of Science and Art. By J. C. Buckmaster, *B.A.*

The author referred to the origin of mechanics' institutions, and the influence of the Society for the Diffusion of Useful Knowledge. The want of a better elementary education was the great obstacle to further improvement. The Royal Dublin Society, the old schools of design, and the industrial museums of Ireland and Scotland were intended to promote, in a variety of ways, a more general knowledge of those arts and sciences which relate to our national industries. In 1852 all these institutions were united under the Board of Trade into a Department of Science and Art. The old schools of design were superseded by drawing-schools or schools of art, and 90 of these schools are now in active operation, teaching the elements of art to 92,000 persons, of whom the larger number belong to the working classes. In 1857 the Science and Art Department was placed in connexion with the Committee of Council on Education, and in 1859 a very comprehensive Minute was passed for aiding instruction in the elements of all the natural and applied sciences. There is annually held at South Kensington an examination for teachers of elementary science, which is free to all who give notice of the subjects on which they propose to be examined. The State avoids all the responsibility and expense of training teachers and providing them with employment. At the first examination, in November 1859, there were 57 candidates, of whom 49 were successful; in 1860 there were 89 candidates, of whom 75 were successful; in 1861 there were 103 candidates, of whom 97 were successful. By far the larger number of certificates have been taken by elementary teachers; but certificates have also been taken by a weaver, a printer, a wheelwright, clerks, and assistants in shops. Wherever a class is established, there must be a local committee of at least five persons. This committee superintends the examination of the pupils, which is conducted on the same principle as the Oxford middle-class examinations. For every pupil of the industrial classes who has received 40 lessons from the teacher, and who passes a satisfactory examination in the elements of the subject taught, the teacher receives a payment of £1, and for every first, second, and third grade Queen's prizeman he receives higher payments. The successful pupils receive rewards of books and medals. The department is merely an examining body: it does not pretend to interfere in any way with local organization and authority. All that is looked for is a successful result, and on this the teacher receives his payment. The examinations this year were held in May in 75 places; 60 of these were in connexion with mechanics' institutions. Last year only 563 pupils were examined; this year 1260, of whom 1038 were persons belonging to the industrial classes, and their ages varied from 9 to 53 years.

On the Cotton Famine, and the Substitutes for Cotton. By David Chadwick, *F.S.S., Honorary Secretary of the Manchester Statistical Society.*

The civil war in America has stopped our supplies of cotton from the Southern States, which during many years have supplied us with more than three-fourths of our total consumption. In 1860 we received the following supplies of cotton:—United States, 2,581,000 bales; Brazil, 103,000 bales; Egypt, 109,000 bales; West Indies, 1000 bales; East Indies, 563,000 bales; total, 3,357,000 bales. The total amounts of cotton imported into Liverpool in the two periods of $8\frac{1}{2}$ months were respectively as follow:—To September 1861 ($8\frac{1}{2}$ months), 2,508,672 bales; to September 1862 ($8\frac{1}{2}$ months), 725,917 bales; deficiency, 1,782,755 bales. The average price of New Orleans cotton, in September 1861, was from $7\frac{3}{8}$*d.* to 10*d.* per lb.; in September 1862, from 24*d.* to 30*d.* per lb.; increase $16\frac{5}{8}$*d.* to 20*d.* per lb., or more than 200 per cent. In ordinary times the price of yarns (40's) has been from 4*d.* to 5*d.* per lb. more than the price of the raw cotton, and a proportionate additional price for weaving. It is now (September 1862) no unusual thing for the spinner and manufacturer to take orders for the yarn and the cloth at the market price on the day of sale of the raw cotton from which it was made. These facts may be taken as sufficient to indicate the unparalleled extent of the present cotton crisis. It has frequently been asked why the cotton manufacturers have allowed themselves to be to so large an extent dependent on one source of supply. It may be answered that cotton-spinners, like all other tradesmen, have gone to the best and cheapest market. The Southern States of America have hitherto supplied cotton of a better and more uniform quality, in larger quantities, and at a cheaper rate than any other country. Why should the cotton manufacturer be blamed for doing that which every other good tradesman does? But Lancashire has not been unmindful of the rapid increase in the consumption of cotton, and the danger of depending so largely on one source of supply. Mr. Bright's committee on India twenty years ago, the Manchester Chamber of Commerce for the last twenty-five years, and the Cotton Supply Association during the last few years have been continuously calling the attention of all the countries capable of growing cotton to the necessity of new sources of supply. India affords the means of supplying us with three-fourths of all the cotton consumed in Great Britain, and the remainder of our wants could be well supplied by Brazil, West Africa, Egypt, Turkey, and Australia. The misgovernment of India, as shown by the want of roads, ports, and irrigation works, and of that security for capital which will induce private enterprise, is the cause of the vast resources of that great country remaining for so long a period comparatively undeveloped. If contracts could be legally and more promptly enforced, and the restrictions on the purchase of land removed, as recommended by Lord Canning, Lord Stanley, and Mr. Laing, there would be some hope that India would be able to compete successfully with America in the cotton markets of the world. Two years ago the Manchester Cotton Company was established, with a capital of £1,000,000. The company entered into negotiations with the government, who promised to make a new road leading from Darwhar to the new port of Sedashegur, and to improve the harbour at the latter place. On the faith of these promises, the company sent a special commission to India, a staff of engineers, mechanics, workmen, and clerks, and have forwarded two shiploads of improved machinery for cleaning and packing cotton. The cotton company find that the road and the pier are not made as promised, and no reasonable progress is being made with the work. The company's efforts have thus been frustrated, and an immense loss sustained by the vexatious delay which has been occasioned. With such a result, is it surprising that private capitalists refuse to embark in commercial enterprises in India? Other cotton companies have been started, viz., The Jamaica Cotton Company, East India Cotton Agency Company, Venezuela Cotton Company, Western Australian Cotton Company, East India Irrigation and Canal Company; and proposals have been made for a Natal Cotton Company, an Asia Minor Cotton Company, an Ottawa Cotton Company. How has the cotton famine affected the working classes? There are upwards of 500,000 persons employed in the cotton manufacture, of which nearly 400,000 are employed in Lancashire. It may convey a better idea of this number to say that it is equal to 25 towns of 20,000 inhabitants each, all wholly engaged in the cotton trade. The engineers, mechanics, and the workers in iron, steel, brass, copper, tin, and wood, and the shopkeepers and other tradesmen supported by them, may be reckoned in addition at half that number (250,000). The women and children and those not able to work, and dependent entirely on the cotton operatives, may also be taken at 250,000. The total number of persons dependent upon the cotton manufacture may therefore be taken at 1,000,000 persons, of which 800,000 are in Lancashire and the immediate neighbourhood. Lancashire, in 1861, contained 2,464,592 inhabitants, or about one-eighth of the population of England and Wales. Of the 400,000 persons usually employed in Lancashire, more than 150,000 are now entirely out of employment, and more than 120,000 are working short time. Taking those working short time at three days a week, and reckoning them at half the number (60,000), it gives 210,000 persons now totally unemployed. By a careful investigation into the rate of wages in 200 trades and occupations in Lancashire in 1859–60, the author found that the average wages paid to the cotton factory operative was 10*s.* 3½*d.* each per week, reckoning men, women, and children. Taking the average earnings of the 210,000 persons now thrown out of employment at 10*s.* per week, the total loss amounts to £105,000 per week, or £1,365,000 per quarter, or £5,460,000 per year. This estimate is likely to be doubled before Christmas next, and, including trades dependent upon the cotton manufactures, the loss of wages may be taken at £200,000 per week. This grievous calamity falling upon an industrious, high-spirited, and hitherto independent class of people, has found them comparatively unprepared to meet the great emergency. Many who had saved a little money in savings-banks, building-societies, and cooperative associations, have stinted themselves of the actual necessaries of life rather than withdraw the whole of their hard-earned savings. Others less provident, or having large families of young children, have been compelled immediately on the cessation of work to apply for relief. Seeing the great distress occasioned by a short supply of cotton, the important question arises, have we any available substitutes? The substitutes for cotton, or admixtures, which have been proposed during the last few years may be stated as follows:—Flax, the product of *Linum usitatissimum*, from nearly every country in the world; hemp, the product of a kind of nettle, *Cannabis sativa*, chiefly from Europe and Asia; jute and bast, the inner bark of a species of lime or linden tree, *Corchorus capsularis*, from India; New Zealand flax, a bulbous plant of the lily kind, *Phormium tenax*, from New Zealand; China grass, a nettle of China, India, and the Indian Islands, affording the valuable rhea-fibre; nettle-fibres, obtained from the common stinging-nettle, and other species from the East; Sunn hemps, obtained from leguminous plants, of species allied to the broom, clover, beans, and peas; silk cottons, or Baraguda cotton, the product of a large tree, *Bombax ceiba*, in South America; pineapple fibre, the produce of the pineapple leaves, from the tropics of the Old and New Worlds; plantain-leaf, from which is obtained Manilla hemp, the product of *Musa textilis*, from the tropics; aloe-fibre, or agave, a bulbous plant from South America, the large leaves of which produce abundance of fibre. In the 'Jurors' Report upon the Great Exhibition of 1851,' and the special papers in the 'Journal of the Society of Arts,' Dr. Royle's work on 'The Fibrous Plants of India,' or the reports of Dr. Forbes Watson on the 'Fibres of India,' a large number of fibres are mentioned as cheap, suitable, and sufficient for clothing the natives of several countries entirely independent of the fibre of the cotton-plant. A fibre said to be new, and stated to be available in very large quantities, at a reasonable price, has been forwarded to the author by a foreigner, who refuses to communicate his supposed secret, except upon impracticable terms. Samples of this fibre have been freely submitted to the merchants on 'Change in Manchester and Liverpool, and obtained general appreciation for their attractive appearance. They are long in the staple, somewhat mixed, silky, and fairly white to the eye, but somewhat harsh and rough to the touch. The samples show great delicacy in the shades of dye in the wool. It is stated to be very suitable for mixing with wool, silk, or cotton, or to be worked alone; but no sample of weaving has yet been sent by the inventor. An establishment has recently been founded in Manchester with the object of testing all fibrous materials and ascertaining the purposes for which they may be used. Samples were recently shown, and an offer made to supply forty bales per week during the next twelve months, of a fibre said to be suitable for mixing, which was strong, of good colour, and of a length and uniformity of staple suitable for cotton machinery, thus presenting the three main conditions required in a substitute for cotton. The price of this fibre, which appears like a mixture of jute and rhea, is said to be less than half the present price of Surat cotton. To all inventors, discoverers, and pioneers in the large and fertile fields of fibre fabrication or adaptation, we venture to recommend that they should avoid secrecy, and avail themselves of the power of patenting their improvements, so that no unnecessary delay may occur in putting to the test of practical experiment every intelligent suggestion that may appear in any degree likely to afford relief to the fearful distress now prevailing in the cotton districts. The general feeling appears to be that no new fibre is likely to be a substitute for cotton, but that several of those proposed may be useful and valuable admixtures with cotton, silk, wool, flax, and alpaca.

In further illustration of the extent of the distress in the cotton districts, Mr. Chadwick furnished tables compiled from the Reports of the Committee for the Relief of Distress in the Manufacturing Districts, dated March 30, 1863.

The following is an abstract of the tables:—

Table No. 1.—The number receiving relief from the guardians and local committees in each district. The total number was 420,243; for the corresponding week in 1861, the number was 39,507.

Table No. 2.—The number working full time and short time, and the number entirely out of work, the estimated loss of wages, and average income. The number entirely out of work was 240,466. Number working short time 166,225. The estimated loss of wages was £184,572 weekly; and the average income per head, including relief and earnings, was 2*s.* 2½*d.* per week.

Table No. 3 showed the total subscriptions received to March 28, 1863.

	£
From strictly local sources	267,987
From general sources	34,331
From Central Committee, Manchester, and Cotton Districts' Relief Committee	324,027
Mansion House Committee, London	321,264
	£947,609

Table No. 4 gave the population and assessment of each district.

Population in 1861..2,013,315. Assessment in 1856..£5,660,390.

On the Numerical Mode of estimating Educational Qualifications, as pursued at the Greenwich Hospital School. By the Rev. G. Fisher, *M.A., F.R.S.*

In Greenwich School, where there were 800 boys, he had adopted a numerical method by which he could arrive at the attainments of any boy. For instance, in writing, he had a standard book: in this book were descriptions of writing of five degrees of quality, and the work produced was judged of according to these results, fractions being used to represent any specimens which might be deemed in quality to be between any of the five whole numbers representing the standards. A similar course was pursued regarding other subjects of instruction, and for examinations, prizes, &c. He had also weighed his boys, and divided them into three groups according to their weight, the three groups varying from 90 lbs. to upwards of 100 lbs. The result of this was that he found the heavy boys and the light ones, as a rule, to possess much about the same amount of talent, whilst the boys who represented the medium possessed the largest amount.

The author insists upon the importance of recognizing and preserving some standard specimens of examination-questions in educational subjects, such as might be generally agreed upon, as explanatory of their nature and difficulty, and which might be adapted to a *numerical scale* of estimation, upon a plan similar to that which he has carried out in this school with great success for more than twenty years. By such means, *absolute* as well as *relative* values of acquirements can be assigned to a considerable amount of accuracy, and the amount of educational work done in various public and private schools be compared with each other. He submitted a diagram to the Section exhibiting, by means of differently coloured lines adapted to a scale, the attainments of the boys at different periods, keeping in view the same standards of estimation. The author stated, in conclusion, that he had no motive in making this communication beyond the desire of exciting attention to the subject, in order that it might lead to the adoption of a sound practical system of testing and recording educational qualifications of a general character; not simply of a *comparative* and numerical kind (which is common in many educational establishments), but of a *permanent* nature, so as to be available for the future as well as the present time, and that we may not be under the reproach of being "unable to hand down to posterity, statistical information of such value as will mark the progress of education."

On Endowed Education and Oxford and Cambridge Fellowships.

By James Heywood, *F.R.S.*

Mr. Heywood defined an endowment to be a charity, and explained that many of the charities of the country were under the control of a Commission which sat in St. James's Square. He thought it advisable that the Universities should be also controlled by some influential board, such as the Committee of the Privy Council. He next referred to what he considered to be the prejudicial influence which he thought was often exerted upon the education of the country by the course of study pursued at the University, and he quoted the instance of a school containing eighty boys, in which scarcely anything was taught but classics and mathematics, simply because a certain number of these boys were prepared for the Universities. He thought that such an evil would be remedied if the course of study were more extended, and if other more practically useful subjects—such as the modern languages, natural and moral sciences—were more encouraged in the University. He also thought that the students of the University ought to be instructed in subjects which would be more practically useful to them in after-life. He desired that some scholarships and fellowships should be given to those who passed a successful examination either in modern languages or in the moral or natural sciences.

When the British Association for the Advancement of Science, some years ago, met at Cheltenham, the Rev. Dr. Dobson, head master of the Cheltenham College, was asked if more science could not be introduced into the Cheltenham College system. In reply, the head master mentioned, that it was the general wish of the parents who sent boys to the College at Cheltenham that their sons should have that instruction which would enable them to obtain scholarships and fellowships at Oxford and Cambridge. Dr. Dobson was of opinion that an alteration should first be made in the requirements for scholarships and fellowships at the ancient English universities, before changes could be effected in the public school system of this country.

A Royal Commission, presided over by the Earl of Clarendon, has, since that time, been appointed to inquire into the state of the largest and most richly endowed English public schools.

At Oxford, in the majority of cases, college fellowships are exclusively bestowed as the rewards of success in the classical examination for honours, at the time of the Bachelor of Arts degree, and Latin composition is constantly required in all the colleges of Oxford.

College-fellowship examinations govern, in a large measure, the whole system of higher endowed education in England and Wales.

Schoolmasters are frequently selected for the largest grammar schools from the class of college fellows. When installed into the chair of office, it is their highest ambition that their pupils should succeed in obtaining college scholarships and fellowships at Oxford and Cambridge.

Dean Peacock, formerly fellow and tutor of Trinity College, Cambridge, strenuously urged the abolition of exercises in Latin and Greek versification in academical examinations on account of the time necessary to acquire the art of making verses in dead languages, and the speedy loss of facility in composing such verses when the practice of writing them had ceased for some years.

In the examinations for college fellowships at Oxford and Cambridge, exercises in the composition of Latin and Greek verses should no longer be set, and an alternative should be allowed between prose composition in Latin and Greek and more modern subjects, such as translations from English into French and German, questions in English history, and exercises in English composition.

There are about 500 or 600 fellowships in the two ancient Universities of Oxford and Cambridge, of which at least 50 or 60 become vacant every year; a larger proportion of these academical rewards should be set apart for the encouragement of science.

On the Prevention of Crime. By EDWIN HILL, *of the Inland Revenue Office.*

> "Crime walks thy streets, fraud earns her unblest bread;
> O'er want and woe thy gorgeous robe is spread."

The author called attention to the large number of habitual criminals whose sole occupation is to plunder others—a predatory class, harbouring in the very bosom of society, and keeping its ground in undiminished numbers in spite of all the forces brought to bear against it,—the residences of these enemies of society being, for the most part, well known to the police, whole districts in London being notoriously peopled by them. In illustration of the magnitude of this evil, the following particulars were given (in round numbers) from the 'Judicial Statistics' for 1858 and 1861, for England and Wales.

The known thieves and receivers of stolen goods are stated to be 44,000; the prostitutes, 29,000; suspected persons, 39,000; vagrants and tramps, 23,000; making a total of 135,000 individuals believed to be living wholly, or for the most part, by criminal practices. The houses of bad character inhabited or frequented by criminals, 24,000. The cost of repressive measures paid by the rates and taxes, for the year 1861, £2,548,000, in addition to the heavy expenses falling upon individuals, and the loss of time incurred by witnesses, jurors, and others. The loss of property from depredation was estimated by Mr. Redgrave, for the year 1858, at seven millions and three-quarters, making a total loss of upwards of ten millions per annum, attributable mainly to the class of habitual criminals.

To give some idea of the number of crimes due to this class, it was stated that London is believed to harbour some 5000 habitual depredators, who, if taken upon the average to commit but one crime per day each, would commit upwards of a million and a half of crimes in the year.

The moral evils were also noticed; the dread and anxiety suffered by thousands, especially the aged, the feeble, and the timid, the crimes of a few desperate men sometimes spreading panic through the whole country*; the contamination of the young, especially of the children of the honest working man, who often has no means of escaping the localities infected by crime; and lastly, the pitiable fate of the children born amidst crime, who, if they have not the good fortune to die early, have no possible escape from the contamination that surrounds them—many being even *beaten* into crime, and destined to fall ultimately into the grasp of the law to have these criminal teachings then *scourged out of them*, if it be not too late to be possible. Probably not fewer than five or six infants per day are born (in this Christian country) so surrounded by a network of crime as to make escape from this fearful destiny all but impossible.

The writer then observed as follows:—The obstinate vitality of this crying evil impels us to undertake a thorough reconsideration of the conditions of that vitality, with a view to the discovery of some more vulnerable part than has hitherto been assailed, or, better still, of some one vital condition that it may be possible to withdraw altogether.

The command of premises for dwelling, for places of congregation, and for the warehouses, workshops, &c., used by the receivers of stolen goods, the coiners, the illicit distillers, and the thieves' instrument-makers, and, lastly, for the training of young thieves, would undoubtedly appear to be one of the essential conditions of the existence of the predatory class. For had such shelter and harbourage been heretofore *wholly unattainable*, it is not too much to say that the class could never have come into existence. Assuming, then, that the command of adequate premises is a vital condition, it remains only to consider whether, practically, the community has power to withdraw such condition, and (having regard to our Anglo-Saxon dislike to meddlesome or intrusive Governmental interference) whether the object of depriving the predatory class of the command of the premises indispensable to their plundering-operations can be accomplished without having recourse to enactments of an arbitrary and inquisitorial character.

The use of premises is of course obtained by the payment of rent; and as no honest owner of house property would willingly receive rents which he knew or even suspected to be derived from the plunder of his neighbours, it follows that the members of the predatory class can obtain tenancy only from landlords who are ignorant of the vocation of their tenants, or from landlords who are not unwilling to accept the proceeds of crime in payment. But for ignorance or connivance, therefore, the predatory class would cease to be able to obtain harbourage, and must speedily fall into dispersion.

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* "Thieving, with all its terrors, costliness, and enormity, is a dark streak in the otherwise brightening horizon of modern civilization. It flits in the portentous shadows of prison walls; and there is a voice from the echoes of every policeman's footfall, telling of something bad under the surface of society, and cautioning us to beware of the danger. We never retire to rest without feeling that we may be maimed and terror-stricken in our beds, or, waking, may find the hard earnings of honest toil purloined beyond possibility of recovery, by a set of worthless vagabonds who are too lazy to earn their own living, and who, with the cowardly rascality that belongs to them, subsist on the stolen property of others. Will there ever be an end to thieves and robbers? Is there no means of getting rid of this interminable expense, damage, and terror?"—*Cornhill Magazine*, Sept. 1860.

As to the conniving landlords, since there is no moral difference between receiving the proceeds of stolen property knowingly and receiving the stolen property itself, they cannot expect much sympathy, whatever pressure may be put upon them to compel them to act as honest men. Enjoying their property under the shadow of the law, it is intolerable that they should *knowingly* allow their property to harbour those who live by breaking the law.

As regards those landlords whose property is infested by criminals without their knowledge, such could not have happened had the public mind been so far advanced upon the subject as to have recognized it as the plain duty of the owners of house property to refuse tenancy to all persons of doubtful character, *i. e.* to all who could not show, beyond all reasonable doubt, that their rents would be *paid out of honest gains*, and nowise from the proceeds of crime, directly or indirectly. It could not have happened, even, had the interests of the landlords as a body, in the suppression of the predatory class, been well understood, since, in the towns at least, the heavy expenses annually incurred in the repression of crime cannot but fall ultimately upon the house property—seeing that, although the tenants actually disburse the police and county rates, these outgoings are doubtless considered by the tenant in estimating the rent he can afford, it being immaterial to him whether he pays more to the rate-collector and less to the landlord, or more to the landlord and less to the collector. Hence a landlord who allows his property to harbour criminals is a traitor to the interests of the landlord body, and would no doubt be so stigmatized had the subject undergone that long and earnest discussion which must have ended in the formation of a strong and healthy public opinion regarding it.

Had such public opinion been now existent, nothing further would have been needed than to find the means of restraining the *few* unscrupulous landlords who, for the sake of high rents, *from whatever tainted source obtained*, would set public opinion at defiance. The matter, however, has to be dealt with under existing conditions. The question therefore is, In what way can the law most readily deal with house property so as to induce its owners wholly to shut out the thief, his aiders and abettors—so that the landlord's absolute rule may be, "No honesty, no house"? The answer is, that the pressure of the rates now levied for the repression of crime, viz. the police and county rates, &c., do constitute an ample force adapted to this purpose, lying ready to our hands, and requiring only to be rightly wielded. It is but to "put the saddle on the right horse." It is, in truth, simply a question between the great majority of householders who do *not* suffer their property to harbour the plunderers of their neighbours and the small minority who *do*.

Now the law, judging between these parties, might justly say to the offending minority, "But for the shelter you afford the predatory class, that class must be wholly dispersed, and the heavy burden of its repression thenceforth cease. Therefore either do as your fellow-landlords do, and so sweep away the burden altogether, or prepare to take it wholly on your own shoulders; justice will not allow that loss to fall upon the whole body, which, but for the laches of a few of its members, would be got rid of altogether." To this it may be added that herein justice and sound policy go hand in hand; for, of all means of getting rid of a preventible evil, surely that of making its continuance a source of loss, instead of profit, to those upon whose will such continuance depends must ever be the most simple and the most certain.

There are two modes of proceeding whereby to fix the cost of repression exclusively upon the property concerned in harbouring the predatory class, viz., 1st, that of directly imposing the amount upon such property, so far as its complicity can be proved; and 2nd, that of exempting from the necessary rates all properties that should be shown to be wholly free from such complicity.

Of these two modes, the latter would be by far the most easy to carry out. For direct imposition being undistinguishable from the infliction of a penalty, the urden of proof would lie upon the parties demanding such imposition, who would f course have to contend with the falsehood, concealment, evasion, and trickery f every kind in which the wrong-doer naturally seeks refuge, and but too often vith triumphant success; whilst the grant of an exemption from the rates would, n the contrary, be the conferring of a privilege, and the burden of proof would of ourse then lie upon the claimant for such privilege, who, unless he appeared with a lear straightforward case, would have no chance of success. Any sign of con- ealment, evasion, or trickery would at once throw the claimant out of court for he time.

Those who are practically acquainted with the difficulty of obtaining legal proof f guilt, in cases in which there is no moral doubt whatever, or none that the per- on accused, if innocent, could not clear up at once, will appreciate the advantage o the community of thus turning the tables upon the supporters of the criminals y whom our towns are infested,—and this without any hardship; for surely those vho have kept their property free from complicity with criminality cannot have ny difficulty in meeting the inquiry whether they have done so or not.

As every grant of exemption would increase the pressure upon those owners who vere unentitled to it, the accumulated weight would soon force them to dispose of heir interests to men who had established such title. By this process our towns vould be soon purified from the predatory class. The whole host of habitual urglars, garotters, pickpockets, forgers, coiners, thieves' instrument-makers, re- eivers of stolen goods, trainers of young thieves, flash-house keepers, &c. &c. &c., vould be dislodged from their dens and hiding-places; and unless they took to onest courses (in doing which every hand should be stretched out to help them), hey would find no shelter other than the workhouse or the gaol; nor, so long as he principle herein recommended were maintained, could they ever regain their ooting amongst us.

The dislodgment of so large a number of offenders, and the total cessation of heir criminal gains, would in all probability necessitate the adoption of some emporary measures to prevent their being driven to desperation. Nor should we orget that, fallen as they are, they are not the less our fellow-creatures. We have nore than once been compelled, by the occurrence of violent epidemic disease, to nake temporary provision for the shelter and maintenance of portions of our own population; and some analogous provision would probably meet the circum- tances in view. Whatever difficulties might beset the state of transition, they nust, from the nature of things, be but short-lived. The final relief would be both reat and permanent.

It may stimulate our zeal to call to mind that which our forefathers accom- lished under analogous circumstances. The "sanctuaries" of the seventeenth entury were not more alien to the ruder times of mounted highwaymen than the xisting "thieves' districts" are to our improved civilization. Macaulay has iven us an instructive account of the suppression of that frightful den of crime, he sanctuary of Whitefriars—"Alsatia," as it was called—of which Sir Walter Scott has left us so lively a picture in "The Fortunes of Nigel." Some 800 known utthroats, robbers, receivers of stolen goods, brothel-keepers, &c. had herded ogether in this "sanctuary" from time out of mind, ever and anon breaking out or the purpose of murder and robbery, as opportunity offered, or as their needs ecame pressing. At length the public patience became fairly exhausted; men roused themselves as from a lethargy; supineness gave way to alarm and resent- nent; the requisite powers were obtained from the Legislature, and at one single ouch of a really firm hand, the ranks of scoundrelism were at once broken and ut to the route, and the whole mass vanished as if by magic.

On the Study of Periodic Commercial Fluctuations. *By* W. S. JEVONS.

It is necessary that all commercial fluctuations should be investigated by the ame systematic methods with which we are familiar in complicated physical ciences, such as meteorology and terrestrial magnetism. Every kind of periodic fluctuation must be detected and exhibited, not only as a subject of study in itself, but because we must ascertain and eliminate such periodic variations before we can correctly exhibit those which are irregular or non-periodic, and of more interest and importance.

Tables of the average weekly accounts of the Bank of England from 1845 to 1861, inclusive, having been prepared, it is shown that there are at least three kinds of periodic fluctuation observable, during the month, the quarter, and the year. The first two kinds are precisely similar in character, though differing much in amount, and are due to the payments of dividends or other claims which occur at the beginning of the quarter and month. Such payments cause a sudden increase of the note-circulation and of private deposits, a considerable decrease of private securities, a slight decrease of the bullion, accompanied by a larger but otherwise similar variation of the loanable capital.

Eliminating such variations from those of the whole year, there remain certain interesting variations due to natural causes, as distinguished from the artificial distinctions of months and quarters. The notes in circulation rise from a minimum in January and February to a maximum in the third quarter, and then very rapidly decrease during November and December.

Private securities greatly increase, and private deposits decrease, about harvest-time, while the bullion and loanable capital undergo a continuous decrease.

These variations are probably due to a great absorption of capital in buying up the proceeds of the year's industry, which have to be held in stock for consumption during the succeeding twelve months.

The bullion and capital, however, have a second maximum in February, and a subsequent decrease until May.

It is also shown, from monthly average determinations, that the rate of discount and the number of bankruptcies suffer a sudden rise after the harvest months. It may be said that there is a periodic tendency to commercial distress and difficulty during the months of October and November. The great commercial panics are aggravations of this periodic difficulty, due to irregular fluctuations.

Of 79,794 bankruptcies which were gazetted from the beginning of 1806 to the end of 1860, 28,391 occurred in the second month of the quarter, 26,427 in the third month, and only 24,976 in the first month, in which occurs the payment of the public dividends.

The price of consols and the price of wheat exhibits a double minimum during the year.

Notice of a General Mathematical Theory of Political Economy.
By W. S. Jevons, *M.A.*

1. The main problem of economy may be reduced to a rigorous mathematical form, and it is only the absence of exact data for the inductive determination of its laws or functions which will always prevent it from becoming an exact science.

2. A true theory of economy can only be attained by going back to the springs of human action—the *feelings of pleasure and pain* which accompany our common wants, and the satisfaction of those wants by labour exerted to that purpose. These feelings are the commonest motives of action; but other motives of a moral or religious nature must be recognized by the economist as outstanding and disturbing forces of his problem.

3. Feelings of pleasure and pain vary in *intensity* and in *duration*. They have two dimensions. The *quantity* of feeling, therefore, resembles an *area*, and is got by integration of the function which expresses the relation of the intensity to the duration.

4. Pleasure and pain are opposed as positive and negative quantities.

5. Anticipation of future pleasure or pain gives a less degree of present feeling related to the anticipated feeling by some vague function of the intervening time peculiar to each person's character.

6. A *useful object* is that which causes pleasure, either by present use or by expectation of its future use.

7. *Amount of utility* corresponds to amount of pleasure produced. The use of

onsumption of successive equal increments of a useful substance does not usually roduce equal increments of pleasure, but the *ratio of utility* on the last increment sually decreases as some function of the whole quantity consumed. Let this be alled the *final ratio of utility*.

8. Labour is accompanied by pain, and will be exerted both in intensity and luration until a further increment will be more painful than the increment of proluce thereby obtained is pleasurable.

9. The abilities of two men in producing the same or of one man in producing eneral kinds of useful objects are very various, contrary to the erroneous assumpion of Ricardo.

10. When two persons, each possessing a known quantity of a commodity or seful substance capable of division into small quantities, exchange with each ther, the unknown quantities which pass between them are determined by *two quations*, involving the known quantities of commodity previously possessed and he functions expressing the final ratios of utility of those commodities. It is also necessary condition of the exchange that any portions of the commodities, and herefore the last small portions, are exchanged in the same ratio as the whole uantities.

11. When there are more than two persons or commodities, a simple law of ombinations gives the numbers of equations which will determine all the quantities assing in exchange. The whole system of trade, howsoever extensive, is thus heoretically represented by a system of equations.

12. When the quantities of commodities are considered as produced by labour nder the conditions stated in (8), a new set of equations will determine, in conunction with the equations of exchange, the new set of unknown quantities introluced. Any system of production and trade is thus theoretically represented.

13. *Capital* is defined to be simply *maintenance of labourers while they are waiting the results of labour employed in a manner which does not give immediate eturns.* As maintenance may be applied indifferently to any branch of industry, he interest of all (free) capital is the same. The interest is determined by the atio which a new increment of produce bears to the increment of capital by which t was produced. It is shown to be a simple mathematical result of the above conlitions that the interest of capital always tends to fall rapidly as its quantity in roportion to labour increases.

14. When the remaining parts of the theory are completed, it will probably be hown that the *rate of wages* is the average produce of labour after deduction of ent, interest, profit, insurance, and taxation. These are so many payments which he labourer makes for peculiar advantages enjoyed.

On the Definition and Nature of the Science of Political Economy.

By HENRY DUNNING MACLEOD, *B.A.*

The author said, as the science of political economy was daily growing in importance, and was now made a subject of examination in the public services, its ature and objects should be settled, as these points had not yet been decided by conomists. Ever since it was founded, its cultivators had declared that it was a hysical science, and that it should be investigated in a manner analogous to that n which the researches of physical science were conducted. If this were so, it must obey the well-understood conditions of a physical science. These were that t must be some large body of phenomena all founded on a single idea of the most eneral nature. The purpose of the science was to discover the laws of these phenomena. It must also be based upon certain conceptions and axioms which must e perfectly general. If political economy were therefore a physical science, it must be some large body of phenomena all based upon a single idea, and it must be based upon conceptions and axioms of the same wideness and generality as those of physical science.

Like many other sciences, political economy had undergone some changes of conception since it was founded. At present there were two definitions which divided economists. First, *that it was the science which treated of the production, distribution, and consumption of wealth.* This definition was first given to it by J. B. Say.

The second was, *that it was the science of exchanges, or of value*, or the philosophy of commerce. This definition was first given to it by Condillac, who published a treatise on economic science in 1776, the same year as that in which the 'Wealth of Nations' was published. This was neglected at first; but, as in so many other cases in science, Condillac's idea was now rapidly gaining ground, and it was the one to which the majority of recent economists were now gravitating. The object of the paper was to consider which was the better definition. The first requisite of a good definition was that it should be clear and distinct. In the first definition, production, distribution, consumption, and wealth were wholly unexplained. Scarcely two economists were agreed as to what wealth meant, or were consistent with themselves in its use. All were agreed, however, that corn, clothes, &c., were wealth. The production of corn, clothes, &c., was the production of wealth. If, therefore, political economy treated of the production of wealth, it might be supposed that it treated of the business of farming, manufacturing, &c. But every one knew that economic science had nothing to do with the arts and processes of farming, manufacturing, &c.; it had nothing to do with the arts and processes by which things were obtained, but only with their price or value when obtained. Production must, therefore, bear some very technical meaning not apparent at first, and therefore it should not be made part of the definition of the science. Every lawyer and merchant knew that a debt was a species of property. The business of banking consisted in buying debts by creating other debts. It was by no means easy to see how buying debts with debts came under the idea of the production, distribution, and consumption of wealth.

The interpretation of wealth was full of perplexity. No man could tell what Adam Smith meant by wealth. But as economic science treated of wealth, we must consider what that quality of things is in regard to which they are considered as wealth, and how they came into the science of wealth; and that quality being settled with regard to any one of them, it must be generalized so as to include all quantities which possessed that quality. The Abbé Baudeau had a very instructive passage, in which he showed that things were wealth solely from being exchangeable; so long as they were exchangeable, they were wealth; when they ceased to be exchangeable, they ceased to be wealth. Here, therefore, was the general conception of wealth—exchangeability. Hence, if political economy was the science of wealth, it must be the science of the exchangeable relations of quantities. This was now the conception adopted by the majority of modern economists; and we at once saw that it answered the conditions of a physical science. It was a distinct and circumscribed body of phenomena, all based upon a single idea. It was a new order of variable quantities, and of course the theory of the exchangeable relations of quantities must be brought into harmony with the general theory of variable quantities. Adopting exchangeability as the test of wealth, all exchangeable quantities must be included in it. These were of three distinct species:—(1) material products, (2) what were usually called immaterial products, such as the sciences and knowledge, and (3) what was called incorporeal property, such as copyright, shares in companies, the funds, credit, &c. Exchanges of these kinds of property were constantly taking place, and therefore that formed the domain of economic science. The nature of the science was indicated by its name, for *οἶκος* was the technical term in Attic law for private property of all sorts; and economic science determined the laws which regulated the exchanges of property. The foundation of economic science was the right of private property and exchange, which was opposed to Socialism, where the right of private property and exchange was abolished. Such a state extinguished all notion of value, which could not exist without an exchange. Production and distribution together constitute exchange. When persons want to have something distributed to them, they must produce something to give in exchange, and the reciprocal production and distribution form an exchange. The whole body of exchanges, both within the country and with foreign countries, constitute what the majority of modern economists hold to be the domain of pure economic science.

This body of phenomena might be brought under the strictest laws of physical science, and all discordances among economists might be decided by the acknowledged laws of inductive logic. It could easily be shown that the modes of investi-

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gation current among economists were utterly repugnant to the fundamental principles of natural philosophy.

It was already implicitly acknowledged that it was a mathematical science. In any book of Algebra it was said that money was a positive quantity, and debts negative quantities. Each were exchangeable, and therefore economic quantities. Here, therefore, were positive economic quantities and negative economic quantities. Now mathematicians had fully explained the meaning of negative quantities and the use of the negative sign in the various physical sciences, but no mathematician had explained the meaning of negative economic quantities and the theory of the negative sign in political economy. Nevertheless it was of the highest importance to do so. Under the simple fact remarked by algebraists that debts were negative quantities, there lay hid a new and magnificent branch of economical analysis, which contained the solution of the theory of credit, and all other incorporeal property, which constituted at least 95 per cent. of valuable property, which was wholly omitted from economic works.

Adopting the conception of exchanges, a great new physical science was presented to us, fitted to be raised to the rank of an exact science; for it was found that the laws of exchange were absolutely the same in all ages and countries. Economic science could therefore be raised to the rank of an exact science, because it was based upon principles of human nature as permanent and universal as those of physical substances upon which the physical sciences were based.

On the Utility of Colonization. By HERMAN MERIVALE.

The author drew a distinction between the benefits of colonization, which for his purpose he assumed to be admitted, and those of retaining the government of colonies after they had become settled communities. As to the latter, he observed that the following was the simplest mode of stating the question. How far is the profitable application of the accumulated knowledge, capital, and labour of an old country to the production of wealth in a new country aided by the circumstance that both are under the same government? But passing over at present the general problem, he confined himself to a single portion of it, namely, how far the advantage which we derive from emigration as an outlet to our people might be affected by any political change involving the loss of our colonial empire.

He then entered on a variety of statistical details to show that the peculiar advantage of emigration, as now carried on, consisted not only in its extent, but in the regular manner in which it controlled the progress of population. He showed that since the year 1845, when the potato-disease commenced, the increase of population in the United Kingdom, taken together, had been scarcely greater than in France during the same period. In England and Wales however, taken alone, the natural increase had been about 10 per cent., in France about 4 per cent. only. And yet, in the same period, England and Wales had probably sent out a million of emigrants, France none (that is, the immigration into that country nearly balanced the emigration). In the same period, in England and Wales, the following circumstances had coincided:—large emigration, increase of the number of births, increase of the number of marriages, with no diminution in the average length of life, indicating no diminution in the comfort of the people. Emigration has provided for about one child in six, and thereby enabled the people of England to marry as early as before, and to have as many children, without any pressure of our population indicated by decline in the national well-being. In France, the same period exhibited these facts:—no emigration, a due relative increase in the number of marriages, no diminution in the public well-being, as indicated by mortality, but rather an increase. The inevitable consequence which these facts indicated was, as the author observed, that there must have been a diminution in the number of births to a marriage. And this was completely borne out by the facts. The annual number of births remained absolutely stationary throughout the period. The ratio of births to a marriage was continually diminishing (from 1822 to 1831, 3·64—now about 3). Marriages were less productive, either from being contracted later or from other causes; and the progress of population was, in our country, in a more normal and healthy condition, owing to the resource which emigration afforded.

It was, however, obvious that if a foreign country would receive our overflow as readily and as regularly as a colony, England gained nothing, in this matter of emigration, by retaining her dominion over the latter. And this had been the case for very many years. The United States had afforded greater facilities to emigrants than any or all our colonies, and had attracted them in greater numbers. But the present state of that republic seems to preclude all reasonable hope of the continuance of those facilities to anything like the same extent. Clearly not, if it separated into a number of distracted and indebted communities, with hostile feelings to each other; probably not, even if the union could be restored. He therefore argued the great importance of maintaining our political tie at the present moment with those colonies which absorb our emigrants—Canada and Australia; the latter beginning already to receive so large a number as to show a figure of some importance in our returns. And, without laying too much stress on numerical statements having reference to so short a period as the last two years, he thought there were already signs of a serious stoppage of emigration in general, and of a comparative diversion of that which exists, from the States to the colonies.

On the Training and Instruction of the Unemployed in the Manufacturing Districts during the present Crisis. By the Rev. W. N. Molesworth, *M.A.*

The author of this paper stated that he read it rather with a view of obtaining suggestions than of imparting information. He then proceeded to give a brief account of the operations of the Rochdale committee for the instruction of the unemployed. The object of that committee was to educate the unemployed adults during a portion of the hours in which, under ordinary circumstances, they would be at work. The teachers were persons who had volunteered their services from among the unemployed themselves*, the teaching being in fact very similar to that of the Sunday schools; the branches of education taught in the schools were reading, writing, arithmetic, and elementary geography. In addition to this, some gentlemen in the town had given readings or lectures on various subjects; and on these occasions the scholars were encouraged to ask questions, and to enter into a conversational discussion of the topics treated by the lecturer. Of course the instruction given in these schools was very imperfect; still it was appreciated by the men, who were evidently very grateful for the efforts made for their improvement, and anxious to profit by them. The committee had only just commenced their operations, and were much cramped by the want of funds†. They were gradually feeling their way towards something higher and better, and he was sure that they would be very thankful for any suggestions that might be contributed by the eminent educationists present in the Section, in the course of the discussion which would follow the reading of the paper.

Local Taxation and Real Property. By Frederick Purdy, *F.S.S., Principal of the Statistical Department, Poor Law Board, London.*

In the schemes recently brought before the public for the partial or complete revision of British taxation, none, so far as I am aware, has recognized the claim to consideration which the large and constantly increasing revenue raised under the designation of "local taxation" possesses.

The question of our local imposts ought not, in any discussion of the equitable re-adjustment of the taxation of the kingdom, to be ignored. Obviously the money expended for the relief of the poor, for the formation and the repair of the public highways, for the prevention or for the punishment of crime, for the sewerage and sanitary regulations of towns, and for the other various objects of public utility for which local taxes are raised, is as necessary to the maintenance of the country in its political, social, and economical integrity as the imperial expenditure for the Army, the Navy, or the Civil Service.

The information collected under the powers of the Local Taxation Returns Act of 1860, and recently published by the Home Office, is supplementary to the Returns of Local Taxation in England and Wales published by other departments. Therefore, as regards England, we have at length a complete account of the amounts raised and expended for local purposes. With respect to Scotland and Ireland the amounts of two or three of the principal local taxes are officially published, and the others are approximately known. Hence we obtain a close approximation to the entire amount of the local taxes of the United Kingdom.

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* Paid masters have since been engaged, the teachers remaining as monitors under them, with a payment of 1*s.* each.

† This would have been amply supplied by means of the Australian grants.

The majority of these taxes are incident upon real property; the residue falls upon personal property. This distinction will be observed in the subsequent classification.

As regards *England and Wales*, the figures given hereafter chiefly relate to the year 1860–61, though in a few instances the returns refer to an earlier date.

1. The poor's rate is by far the heaviest of our local taxes; with this rate the largest portion of the county, borough, and police rates is raised; but, for the sake of a clearer classification, these latter rates have been deducted, leaving a total almost exclusively devoted to the relief of the poor. In 1860–61 this sum was £5,996,409. This was quite independent of all payments from Her Majesty's Treasury, and of other receipts in aid of poor's rates.

2. The amount of county, borough, and police rates paid out of the poor's rate in the same year was £1,925,210.

3. In many places the borough rate is levied separately; in 1854 it amounted to £311,953.

4. Highway rates in 1859, inclusive of labour given by parishes in lieu of payment of rates, amounted to £2,065,841.

5. Church rates in 1860–61 were returned as £233,560.

6. Sewers' rate in certain districts, not metropolitan, £35,323.

7. Drainage and Embankment rates, £65,672.

8. City of London Commission of Sewers, £21,058.

9. Rates raised by the Metropolis Local Management Board, £788,189.

10. Metropolis Main Drainage, £161,017.

11. Rates raised by Burial Boards, £103,707.

12. Rates raised by Local Boards, £850,578. These, together with two small sums for lighting and watching, and for Improvement Commissions, constitute an aggregate of £12,582,277 leviable on real property.

The other taxes are—

13. Turnpike tolls (inclusive of parish compositions), which in 1859 amounted to £1,126,465; whence it appears that the cost of the highways and turnpike roads in England and Wales is nearly £3,200,000 a year.

14. Harbours, 1860–61, amounted to £1,201,398; and

15. Trinity House dues, in 1861, to £288,313. These three rates form a total of £2,616,176, and are incident upon personal property.

The grand total raised in *England and Wales*, therefore, as the local taxation for one year, was £15,198,053.

As regards *Scotland*,

1. Poor's rates in 1860–61, inclusive of £18,159 collected at church doors, £646,871.

2. Cost of police in counties and burghs, in 1852, £76,609; prison-rate assessment in 1860, £36,107. It is believed that there are other items of local taxation, but they are not easily discovered. The total of these three rates is £741,428, all incident upon real property.

3. Turnpike tolls and Highland roads and bridges in 1858–59, inclusive of revenue from other sources in aid, £233,337.

4. Northern lights in 1860, £59,747. Total £292,084, falling on personal property.

The aggregate (and it can only be regarded as an approximate one) is £1,035,512.

As regards *Ireland*,

1. Poor's rate in 1860–61, including the cost under the Medical Charities Act, £689,229.

2. Grand jury presentments in 1860, amounting to £1,034,927. These presentments, it should be observed, defray charges similar to those provided for by the county and borough rates of England.

3. Dublin police in 1852, £38,324. Total £1,732,480, falling upon real property. This, like the similar charge for Scotland, must be considered as a close approximation only.

4. Dublin Ballast Board in 1860, £46,658. This charge falls upon personal property.

The grand total for *Ireland* is £1,779,138.

Gathering the totals together for the three kingdoms, we are presented with the following summary:—

Amount of local taxes

(*a.*) Incident upon real property.	£
England and Wales	12,582,277
Scotland	741,428
Ireland	1,732,480
Total	£15,056,185

(*b.*) Incident upon personal property.	£
England and Wales	2,616,176
Scotland	292,084
Ireland	46,658
Total	2,954,918
Grand total	£18,011,103

Hence it appears that the real property of the United Kingdom pays the large sum of £15,056,000 for local taxation, before it comes under the hand of the collector of imperial taxes. The amount of imperial taxation which this description of property has to bear can only be given roughly, because some of the items clearly chargeable thereto cannot be eliminated from the general mass. These imposts are, however, so far as known or capable of estimate, as follows:—

	£
Land Tax	1,145,341
House Duty	822,936
Succession Duty	605,196
Stamps on Deeds (say one-half)	664,000
Fire Insurance (say one-half)	742,000
Property Tax	5,472,281
	£9,451,754

Therefore the amount of taxation, local and imperial, paid out of real property is £24,508,000. The annual value of real property, assessable under head Schedule A, was in 1861, in

	£
England and Wales	105,464,061
Scotland	13,212,882
Ireland	13,003,554
	£131,680,497

From the foregoing statistics it appears that the rate in the pound on real property in this country is, in respect of

	s.	*d.*
Local Taxation	2	3½
Imperial Taxation	1	5¼
Total	3	8¾

Real property pays 2*s.* 3½*d.* in the pound for local rates, before it comes on to the Chancellor of the Exchequer's Budget for further taxation.

Advocates for the reform of the Income and Property Tax Acts propose to relieve the holders of precarious incomes of some part of the present impost by throwing a larger charge upon the possessors of permanent incomes; but a considerable portion of the latter derive their income, or portions of it, from real property: it is therefore a proposal, so far as they are concerned, to increase the load upon their property, already unduly burdened by the local taxation of the country.

On the Pauperism and Mortality of Lancashire. By FREDERICK PURDY, *F.S.S., Principal of the Statistical Department, Poor Law Board.*

1. To bring under the notice of the Section some of the statistical data which represent the pauperism and mortality during the six months ended at Midsummer last, in the cotton districts of Lancashire and Cheshire, is the object of the present communication. No attempt has been made in it to explicate those involved and complex causes which find their most significant numerical exponents in the mortality tables of the Registrar-General. The distress which has fallen upon the operatives of the cotton districts has not ceased, but is apparently deepening as the winter approaches. It would be futile to attempt anything like a satisfactory analysis of the phenomena before they cease, and while we are, therefore, necessarily ignorant of the extent and character of their ultimate development. Beyond this, it is essential to a scientific elucidation of the connexion which exists between distress and mortality in any place that the investigator possess both hygienic and local knowledge of the district under review—qualifications usually looked for in active and intelligent local officers of health. Though the writer can throw no light, by the aid of those qualifications, upon the facts hereafter noticed, he hopes that at the present time the important social questions which are involved in these statistics will constitute a sufficient claim upon the attention of the Section.

2. It is too well known that when the labouring classes suffer from a collapse in trade or manufactures, the immediate effects upon very considerable numbers are a deprivation of the comforts and a diminution of the necessaries of life, with increased sickness and mortality following in the wake. Then pauperism emerges among families where, in prosperous times, it was never known, and becomes, under ordinary circumstances, not only the index, but the measure of distress. Pauperism, though it may indicate, ceases to measure distress when thousands are thrown out of their usual employment by the paralysis of a vast industry like the cotton trade of Lancashire. The lower and less thrifty class of operatives soon come upon the rates; the more provident and respectable families, after exhausting their means, keep off the rates till the last moment, or eke out their means by the aid of private charity, and so contrive for a time to avoid the pauper-roll. The distress, or rather the destitution, would be accurately measured if we knew the numbers aided by private charity, in addition to those who are relieved from the poor-rates. This, however, does not contemplate the deprivations which those labourers, who have honourably striven to live independently of charity, undergo in every form, before they reach that point where all their own resources are exhausted.

3. Lancashire, during the last fifteen years, has been thrice visited with distress. In the year 1846-7 the expenditure for the relief to the poor throughout the country rose over the average of the three preceding years by £261,363, or by 83 per cent. At the same time the deaths in the year increased over the average of the three previous years by 18,181, or 36 per cent. In the autumn of 1857 the district was suffering from the effects of what was frequently termed the "American crisis;" and the distress continued to the midsummer following. The distress, as measured by the increase of pauperism, can, in respect of this period, be exhibited for the twenty-one unions of Lancashire and Cheshire, which contain the principal cotton manufacturing population of the kingdom. During the nine months ended at Midsummer 1858, the deaths in those unions rose 11·9 per cent. The numbers for each quarter are stated below, viz.:—

	Quarters ended 1856-7.	Quarters ended 1857-8.
December	12,667	15,131
March	14,302	15,603
June	13,067	14,088
Total	40,036	44,822

Taking the amount of pauperism at the end of each quarter in the same unions as sufficiently exhibiting the pressure, it will be found that the increase in 1858 was 35·4 per cent.

The number of paupers at the end of each quarter was as follows:—

	Quarters ended 1856-7.	Quarters ended 1857-8.
December	66,950	106,109
March	68,066	91,988
June	63,994	71,407
Average	66,336	89,835

4. The third visitation is that under which the cotton manufacturing districts of Lancashire and Cheshire are now suffering, with every symptom of further aggravation. In the twenty-one unions, inclusive of Liverpool, which comprise, as already stated, the cotton manufacturing district of Lancashire and Cheshire, the number of deaths in the four March quarters last past stood thus:—

1859	15,390	
1860	14,710	
1861	15,889	
Average	15,329	
1862	17,000	increase 1671, or 10·9 per cent.

The number of deaths in the four June quarters last past stood thus:—

1859	13,071	
1860	13,811	
1861	13,789	
Average	13,555	
1862	14,100	increase 545, or 4·0 per cent.

It will be seen hereafter that the pauperism greatly increased in the June quarter of the present year, though the augmentation in the ratio of deaths, as here shown considerably diminished. But the milder weather of the Midsummer quarter may be credited with some, if not the whole, of the difference in the mortality. The aggregate population of these unions in 1861 was 2,067,267. No attempt has here been made to adjust the census returns in respect of prior or posterior dates. Whenever any ratio in this paper is given in relation to the population, it has been computed upon the actual census of 1861. The number of paupers in receipt of relief excluding from the account lunatics in asylums and vagrants, stood in the four March quarters as hereafter stated:—1859, 66,704; 1860, 57,933; 1861, 58,2[illegible]; average, 60,966; 1862, 100,813; being an increase of 39,847, or 65·3 per cent. The number of paupers in the four June quarters was, in 1859, 61,002; 1860, 54,1[illegible]; 1861, 54,731; average, 56,627; 1862, 107,420, being an increase of 50,793, or [illegible] per cent. The rate at which the pauperism rose to its present amount has varied considerably in the different unions of the district.

5. The unions have been divided into three sections, for the purpose of ascertaining what immediate relation the pauperism bears to the mortality. The first or section A, comprises seven unions, with a population of 773,662 persons. In no union of this section had the number of paupers at Midsummer 1862 been more than 100 per cent. in excess, when compared with the numbers relieved at Midsummer 1861. Measuring the ratio of pauperism on the population, we find that at Christmas 1861, when the pressure first became marked, it was 2·7 per cent., or 0·5 per cent. higher than at Christmas 1860. From Christmas to Midsummer last it rose 0·8 per cent.; at the latter date it was 3·5 per cent. In the *following* table the unions are placed according to their pauperism at the end of 1861. The absolute increase per cent. in the number of paupers at Midsummer 1862, as compared with Midsummer 1861, is shown in the last column:—

Section A.—Ratio per cent. of Paupers to the Population.

Unions.	December 1861.	Rise in half-year.	June 1862.	Absolute increase, Midsummer 1862, compared with Midsummer 1861.
Macclesfield....	4·7	0·1	4·8	34 per cent.
Salford........	3·5	0·9	4·4	84 "
Bolton........	3·0	0·4	3·4	41 "
Wigan........	3·0	0·8	3·8	38 "
Bury..........	2·5	1·3	3·8	100 "
Chorlton......	1·9	0·8	2·7	68 "
Oldham......	1·9	0·9	2·8	86 "

Section B. comprises five unions with a population of 442,644 persons. In this section the absolute increase in the number of paupers at Midsummer last was over 100, and under 150 per cent. The proportionate pauperism at Christmas 1861 was 3·6 per cent., or 1·2 more than at the previous Christmas. During the half-year ended with Midsummer last, it rose 2·0 per cent.; therefore at the latter date it was 5·6 per cent.

Section B.—Rate per cent. of Paupers to the Population.

Unions, &c.	December 1861.	Rise in half-year.	June 1862.	Absolute increase, Midsummer 1862, compared with 1861.
Manchester with Prestwich....	5·0	2·4	7·4	127 per cent.
Rochdale........	2·8	2·0	4·8	120 "
Burnley........	2·2	2·3	4·5	145 "
Haslingden......	2·0	0·5	2·5	108 "

Section C. contains four unions, with an aggregate population of 459,547 persons. In this group the absolute pauperism at Midsummer last was in excess of that of Midsummer 1861 by 150 per cent. and upwards. The proportionate pauperism at Christmas 1861 was 3·7 per cent. on the population, or 1·7 per cent. more than at the corresponding season of 1860. During the Midsummer half-year of 1862 the pauperism rose 4·9 per cent.; consequently at the end of June last it was 8·6 per cent. This is by far the most pauperized section of the three.

Section C.—Rate per cent. of Paupers to the Population.

Unions.	December 1861.	Increase in half-year.	June 1862.	Absolute increase, Midsummer 1862, compared with 1861.
Preston......	6·4	4·6	11·0	283 per cent.
Blackburn....	4·4	5·2	9·6	322 "
Stockport....	2·4	4·0	6·4	306 "
Ashton-under-Lyne....	1·9	5·2	7·1	458 "

6. The pauperism of a union is correctly expressed by the ratio which the number receiving relief from the poor-rates bears to the population of the place. The rate of absolute increase in the number of paupers measures more directly the pressure upon the relief-lists, due to the suspension or diminution of the ordinary industrial occupations of a district. For example, the increase in the Ashton-under-Lyne union at Midsummer was 458 per cent., and in the Preston union 283 per cent. But the pauperism of the Preston union was much greater than that of Ashton, being in the former place 11·0 per cent. on the population, and in the latter 7·1 per cent. only. Preston started from a point considerably higher than Ashton, but proceeded with less rapid strides. In Ashton-under-Lyne the converse process took place: similar remarks are respectively applicable to other unions of the cotton manufacturing districts.

7. Three tables have been framed to exhibit the rise of pauperism in the selected unions during the two first quarters of the present year. The first column of ratios in each table shows the percentage of paupers in the last week of December 1860, taken upon the population of 1861, that census being employed as nearer to the truth than any mere estimate. The next column gives the ratios for December 1861. By a comparison of the two, the proportion of pressure in each

union at the close of the last year is shown. The other columns exhibit the ratio at the end of each of the six months ended with June 1860 and 1861. By these means the amount and the velocity of the increase are both traceable. In the seven unions of Table I.*, the ratio per cent. of paupers to population in the last week of 1860 was 2·2; in the last week of 1861 it was 2·7. By the last week of March in the current year it had risen to 3·3, or 0·6 in the three months. By June it was 3·5, or 0·2 per cent. more.

ABSTRACT OF TABLE I. (*Section* A.)

8. This section exhibits the least increase in the pauperism of the district, and that increase took place gradually. Consulting the Registrar-General's quarterly reports of mortality, we find, on comparing the March quarter 1862 with the average of the corresponding quarters of the three previous years, that there was an increase of 604 deaths, or 11·8 per cent., and in the June quarter 354 deaths, or 7·9 per cent. It will be noted from the account which follows that the rate of mortality has not any apparent relation to the increase of pauperism in these unions. In Bury, one of the *least* pauperized of the group, the increase of mortality was very great. In Macclesfield, the *most* pauperized of this section, there was a positive decrease.

Unions.	Difference per cent. in number of Deaths in 1862. March Quarter.	June Quarter.
Bolton	− 1·8	+ 5·8
Bury................	+22·9	+14·4
Chorlton	+ 9·7	+ 8·7
Macclesfield..........	− 0·2	− 8·5
Oldham	+19·7	+ 6·7
Salford..............	+21·5	+16·5
Wigan	+12·7	+ 6·7

The unions of Salford, Bury, and Oldham experienced the highest mortality. Comparing the deaths in the Salford union in the March and June quarters of 1862 with the numbers returned for the corresponding quarters of 1861, it will be found that the increase was 186 and 157 respectively, or 29·4 and 28·3 per cent. The rate at which the pauperism of any locality has been recruited, rather than the height to which it has attained, gives a more correct notion of the distress and consequent suffering. To this end the unions in the next statement are classed according to the rate of increase of pauperism *as measured on every* 100 *of the population.* The union marked by the highest rate of increase between December 1861 and Midsummer 1862 is placed first. Against each union the percentage increase or decrease of mortality is placed, in respect of the half-year ended with June last, and compared with the average of the three previous Midsummer half-years.

Unions.	Increase per cent. of Paupers.	Difference per cent. in number of Deaths.
Salford	2·0	+19·1
Bury	1·9	+19·0
Macclesfield	1·2	+ 4·2
Oldham	1·2	+13·6
Bolton	1·0	+ 1·6
Chorlton	1·0	+ 9·3
Wigan	1·0	+10·1

ABSTRACT OF TABLE II. (*Section* B.)

9. In the five unions of Table II. the ratio of paupers at the end of 1860 was 2·4 per cent.; at the end of 1861 it was 3·6 By the last week of March 1862 it had risen to 5·0, or 1·4 per cent. in the three months. In June it was 5·6, or 0·6 per cent. increase in that quarter. Here similar diversities in the rate of mortality are observable. In the Burnley union, where the pauperism is moderate, and in Manchester, where it is high, the increase in the rate of mortality is very great, and nearly equal.

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* The Tables referred to by Roman figures were in the Appendix to Mr. Purdy's paper abstracts therefrom are printed above.

Unions.	Difference per cent. in number of Deaths. March Quarter.	June Quarter.
Burnley	+22·3	+11·2
Manchester (including Prestwich)	+26·8	+ 0·7
Haslingden	+11·6	− 1·8
Rochdale	− 4·8	− 6·7

If we compare the number of deaths in Manchester in the March quarter of 1862 with those of the corresponding quarter of 1861, we find the enormous increase of 539, or 30·4 per cent.; but in the subsequent quarter, upon instituting a similar comparison, though an increase still appears, it is far below that of the previous three months. In the June quarter the increase was 112, or 7·2 per cent.

Again, ranging the unions according to the rate of increase in the Midsummer six months, compared with the mean of the corresponding half-years of 1859–60 and 1861, we have the subsequent list:—

Unions, &c.	Increase per cent. of Paupers.	Difference per cent. in the number of Deaths.
Manchester and Prestwich	4·3	+14·4
Burnley	2·6	+ 5·3
Rochdale	2·5	− 5·7
Haslingden	1·3	+ 5·3

Abstract of Table III. (*Section* C.)

10. In the four unions of Table III. the ratio of pauperism in the last week of December 1860 was 2·0 per cent.; in the corresponding week of 1861 it was 3·7 per cent. At the end of the three subsequent months it had attained to 6·8 per cent.; by Midsummer 1862 it was 8·6 per cent. The pauperism had risen 4·9 per cent. in the half-year. This is by far the most pauperized section of the district. As regards mortality, the Preston union, the most pauperized of this section, appears to have suffered little; the same observation is applicable to the Ashton-under-Lyne union. The Stockport union, the least pauperized, has, however, suffered the greatest mortality.

Unions.	Difference per cent. in number of Deaths. March Quarter.	June Quarter.
Blackburn	+21·8	+ 5·8
Preston	+10·2	+ 2·3
Stockport	+13·0	+22·1
Ashton-under-Lyne	+ 4·4	+ 3·6

Re-arranging these unions in the order of their rate of rise in pauperism between the close of 1861 and the end of June last, and noting down the comparative death-rate of the Midsummer half-year 1862, they stand in the following order:—

Unions.	Increase per cent. of Paupers.	Difference per cent. in the number of Deaths.
Preston	8·0	+ 6·4
Blackburn	7·3	+14·4
Ashton-under-Lyne	5·8	+ 4·0
Stockport	5·1	+17·2

11. Liverpool has not been classed with the other places in the foregoing tables because, however much that port may have suffered in consequence of the so-called "cotton famine," it evidently stands in a very different category from the manufacturing unions of Lancashire. It has suffered some increase in pauperism, though, in comparison with the other parts of the district, the augmentation may be called very moderate. The contiguous union of West Derby and the large parish of Toxteth Park are so intimately connected with Liverpool, that it is undesirable, in discussing the mortality and pauperism, to regard the latter town separately, though neither of its suburbs appears to have been much affected by the present distress. It is remarkable that while Liverpool exhibits an increase of pauperism fivefold that of the West Derby union (including Toxteth Park), the increase of

mortality in the latter place is very considerable; on the other hand, in the former town there is a positive, though small, decrease in the number of deaths:—

	Increase per cent. of Paupers, 1861-2.	Difference per cent. in the number of Deaths, 1861-2.
Liverpool	+62	− 0·9
West Derby and Toxteth Park	+12	+13·7

12. An interval of three years lies between the commencement of the last and the rise of the present distress in the north. The distress of 1857–8 barely extended over nine months. Counting to Midsummer last, the present suspension of occupations has continued, with increasing severity, for eight months. It will be of interest to contrast the results of the two periods, premising that the figures which relate to 1857–8 are representative of the nine months terminated at Midsummer 1858, while those of 1862 are for six months only. The ratio of pauperism for the earlier period is the average of the numbers relieved at Christmas, Lady-day, and Midsummer; in the latter year it is the average taken in respect of Lady-day and Midsummer. The unions are hereafter classed according to the parity or the disparity of the results at the two periods. 1. Three unions which exhibit corresponding results. 2. Six unions which show in comparison with earlier ratios a diminished rate of increase. 3. Six unions which show in comparison with the earlier ratios an augmented rate of increase:—

	Unions.	Difference per cent. in the number of Deaths.		Difference per cent. in the number of Paupers.	
		1857–8.	1861-2.	1857–8.	1861-2.
(1)	Stockport	+18·6	+17·2	+33	+251
	Bolton	− 1·8	+ 1·6	+26	+ 35
	Oldham	+13·9	+13·6	+37	+ 80
(2)	Wigan	+32·1	+10·1	+30	+ 22
	Chorlton	+26·2	+ 9·3	+63	+ 46
	Ashton-under-Lyne	+26·6	+ 4·0	+32	+313
	Rochdale	− 0·3	− 5·7	+21	+108
	Blackburn	+28·2	+14·4	+38	+301
	Preston	+19·0	+ 6·4	+63	+264
(3)	Macclesfield	−10·3	− 4·2	+49	+ 25
	Bury	+10·0	+19·0	+19	+ 91
	Salford	+11·4	+19·1	+56	+ 75
	Manchester	+ 8·1	+14·4	+80	+117
	Haslingden	−21·3	+ 5·3	+44	+100
	Burnley	− 7·9	+ 5·3	+43	+119

Making the same contrasts between Liverpool and the West Derby Union, we have the following figures:—

Unions.	Difference per cent. in the number of Deaths.		Difference per cent. in the number of Paupers.	
	1857–8.	1861-2.	1857–8.	1861-2.
Liverpool	+20·3	− 0·9	+11	+ 62
West Derby	+26·0	+13·7	+16	+ 12

13. It is satisfactory to know that, whatever may be the cause, the rate of mortality in the distressed unions is, in proportion to the suffering, as indicated by the pauper returns, less now than it was in 1857–8. The Table just given shows that, with one or two exceptions, the pressure upon the poor-rates is much severer now than then; and that, of the sixteen unions selected as the most important in the district, three show the *same* rate of increase in mortality as in 1857–58, seven show a *less* rate of increase in mortality than in 1857–58, six show a *greater* rate of increase of mortality than in 1857–58. But the pauperism of the last six is, in its excess, nearly double that attained in the earlier period.

14. It is evident, from an inspection of the notes appended to the registrars' quarterly returns, that during the nine months ended with June 1858, an epidemic of scarlatina, whooping-cough, small-pox, and measles prevailed in the district

throughout the period, with more or less violence: to these causes must be added many deaths from bronchitis and pneumonia. The registrar of the Hulme district, with reference to the great mortality there in the March quarter of 1858, remarks that "the operative classes have been compelled to economise their resources in every possible way. This has led to an excessive overcrowding of the dwelling-houses amongst the poorer classes; for where in some streets most part of the houses are uninhabited, in others there are as many as two and often three families in one house, badly ventilated and deficient in most sanitary requirements. To this I mainly attribute the increased mortality." It will be remembered, in connexion with the existing distress, that the deaths in the Macclesfield union are below the average. The registrar for the east district states that "very extensive sanitary improvements have been made in sewering and in paving streets and courts in the worst parts of the borough; and the cottages have been also much improved. Where these measures have been carried out the deaths have decreased." The registrar of Wigan remarks, in regard to the June quarter, that "the deaths are very much below the average for the last five years." He observes that "distress prevails greatly, and is on the increase;" but that, to some extent, it has been mitigated by liberal subscriptions. The registrar of Walton-le-dale district, in the Preston union, states that there the "deaths are much below the average, which I think is accounted for by the almost total stoppage of the cotton-mills, the inhabitants of the Walton district being chiefly factory operatives. . . . . . It may seem in some degree to account for the improvement in health amidst such distress if I add that the able-bodied poor in my district are employed in out-door labour." The registrar of Preston remarks that "There are now upwards of 22,000 people out of employment, and entirely dependent on charity of the boards of guardians for support. . . . . But it is gratifying to know that, notwithstanding so much poverty, the rate of mortality has not increased, but decreased." The Registrar-General has made the following remark as to the sanitary condition of the north-western district, which comprises the union counties of Lancaster and Chester, during the quarter ended at June last:—"It was noticed above that the depression of trade in the manufacturing district had sensibly affected the marriage returns; but happily it does not appear that the same cause acting in the opposite direction has tended materially to raise the rate of mortality, and it cannot positively be asserted that it has produced that effect in any degree. England, as has already been mentioned, was generally rather healthier last quarter than in the same season of 1861; but the rate of mortality in Cheshire and Lancashire was, though in an inconsiderable degree, higher last quarter than it had been in the spring of the previous year. The difference was only between 2·408 and 2·417;" that is to say, an increase of nine in every 10,000 deaths. With respect to the increased mortality in Lancashire and Cheshire which the returns for the March quarter of the present year reveal, the Registrar-General had previously observed that "The registrars in certain districts refer the increased mortality, which these figures too plainly reveal, to scarlatina, measles, bronchitis, and pneumonia, which had been prevalent; and by some of them an opinion, which there is reason to fear may be too well founded, appears to be entertained that those complaints had found an active ally in the poverty and want which many of the unemployed thousands now suffer in the great seats of manufacture. Facts have been adduced to prove that in instances of great depression of trade, like that which recently occurred in Coventry, the mortality of children is reduced in consequence of the due amount of maternal care being bestowed on them which in more prosperous times is withdrawn by the important requisition of factory labour. This is within limits. Nursing, in straitened circumstances, may be better for children than fulness of good cheer without it; but when hard times are prolonged, and the small store that had been gathered in the day of full work is exhausted, the greatest amount of parental attention will not expel physical decline, sickness, or death itself from the dwelling."

15. To whatever causes those marked diversities which the paper has shown to exist in the Lancashire and Cheshire unions between the pauperism and the death-rate during the present distress may be ultimately traced, it will be conceded that the mortality tables of that district are matters of the deepest import to boards of

guardians and relief committees. It appears obvious to the writer that if the death-rate in the distressed unions does not permanently exceed, or positively falls below, that of prosperous times, the relief granted to the unemployed operatives and their families is sufficient to maintain them in health. A greatly increased death-rate, on the other hand, must, though it be neither directly nor indirectly the result of insufficient aid, be a source of no little anxiety to those who are now officially or voluntarily engaged in alleviating the wants of the poor. Rochdale, for example, can give little concern to its guardians just now on the score of mortality. But Bury and Salford would in the same matter justify a considerable amount.

Statistics showing the Increased Circulation of a Pure and Instructive Literature adapted to the Capacities and the Means of the Labouring Population. By HENRY ROBERTS, *F.S.A.*

The author of this paper, alluding to the progress of sanitary amelioration, and to his "Notes on various Efforts to Improve the Domiciliary Condition of the Labouring Classes," given *in extenso* in the Transactions for 1860, assumed that, in an enlightened seat of learning, the efforts made to promote a healthy state of the mind and of the immortal part of man, would be deemed equally worthy of attention.

With the progress of popular education in this country, and the unrestricted liberty of circulating works of every description, excepting such as openly outrage morality, the desire of gain led to the production of a large amount of low literature, most objectionable in its character, tending to foster the worst passions of human nature, and stimulating to the commission of crime, as well as to the contempt of all laws, human and divine. In order to counteract an evil so insidious, and one productive of so poisonous a state of the moral atmosphere, it was found worse than useless to have recourse to the law, excepting in a very few instances of its notorious violation. But much greater success has resulted from the various efforts made to supplant and drive out of the field the most injurious of the publications in question, by the introduction of such as are calculated to create a healthy moral atmosphere, to cultivate the mind, inform the judgment, to improve and elevate the taste.

A notice of the efforts made for promoting this object must, on the present occasion, be necessarily restricted to those of leading societies, some of which, as their titles indicate, were formed originally for the exclusive circulation of strictly religious publications, but now combine with that object a more extensive range of pure and instructive literature. These societies will be referred to in the order of their establishment; and afterwards some statistics will be given to show the extent of the circulation of works of the same class by private publishers, which are only illustrative of what is now done for this object, though perhaps on a less extended scale, by many other publishers in the United Kingdom.

The Society for Promoting Christian Knowledge was founded in 1698, by members of the Established Church. It has three distinct objects, one of them being the preparation and circulation of books and tracts, including the Sacred Scriptures and Prayer-books, in various languages; and from this source our army and navy have been largely supplied. The supply of emigrants and the system of lending-libraries has been long a valuable branch of the society's operations, and, with a special view to the latter object, its publications now embrace works on history, biography, philosophy, political economy, natural history, topography, &c., prepared in an attractive form, and written in a Christian spirit. The outlay on the society's publications has averaged, for the last twenty-five years, about £16,000 per annum. Its issues in the year 1860 to 1861 were, of Bibles and New Testaments, 235,592; Common Prayer Books, 339,997; bound books, 1,952,873; tracts, &c., 4,105,611; total of publications in the year, 6,634,073: and from the year 1733, when its issues were first reported, it has circulated 148,902,287 copies of various publications.

The Book Society for Promoting Religious Knowledge among the Poor was established in 1750. Its objects are the gratuitous distribution and the sale of Bibles, Testaments, and books of established excellence, not exclusively religious, as well as the publication of original and standard works adapted to promote religious and moral instruction. It is a rule of this society that no books of a controversial character shall be distributed; and any profits made from the sale of its publications are appropriated to the making grants of books to destitute Sunday and Ragged Schools, &c. The receipts and expenditure of the society for the last year were nearly £5000.

The Religious Tract and Book Society of Scotland, instituted in 1793, sells none but religious books. It was the first society in Great Britain to employ colporteurs in the distribution of approved publications, and it has now from 110 to 120 agents thus employed. Its sale of periodicals in the past year has been above 700,000 copies, and of Bibles and Testaments 20,000 copies.

The Religious Tract Society was founded in 1799, at which period it has been estimated that there were 20,000 hawkers engaged in selling indecent songs and polluting penny papers throughout all parts of the country. The publication of tracts and books for children, with attractive illustrations, was commenced by this society at an early period of its history; and they were followed by cheap editions of old authors, or original works, written in a plain and popular style, to which were subsequently added educational works; and lastly, it was deemed advisable to engage in the production of periodical literature, mostly illustrated, and suited to various ages and classes. Its circulation has increased since 1851 at the rate of nearly two millions per annum, it having amounted in 1851 to 20,887,064, in 1856 to 31,529,185, and in 1861 to 41,883,921. The agency for distributing this mass of good literature is all voluntary, excepting that employed on board of emigrant ships and the sales made through the ordinary channels of trade. The annual receipts and expenditure of the society now exceed £100,000; and the total distribution of its publications has been about 950,000,000 copies.

The British and Foreign Bible Society was established in 1804, for the supply and circulation of the Sacred Scriptures without note or comment. In Great Britain voluntary agency is thus largely employed through the medium of its auxiliaries and branches; and in foreign countries it promotes the same object, often where the Scriptures were before unknown, and even amongst savages, where no written language previously existed. The translating, printing, and distributing of the Sacred Scriptures, in whole or in part, has been promoted by this society, directly or indirectly, in 160 languages or dialects; and the number of versions, wholly or partially completed, is 190, of which 140 are translations never before printed. The issues by the society last year were upwards of 1,500,000 copies, and its total issues of the Scriptures, or portions of them, now amount to 40,910,474 copies. The total receipts of this society were for the past year £168,443 15*s.* 5*d.*, including £76,760 17*s.* 8*d.* for the sale of the Scriptures; and the total expenditure of the society, from its establishment in 1804, has been £5,250,546 13*s.* 6*d.*

The Society for the Diffusion of Useful Knowledge (now dormant) was established in 1826. Amongst its earliest publications was the 'Penny Magazine,' which had at one time a circulation of 200,000 copies. In 1828 it commenced the 'British Almanac,' a publication which has greatly conduced to the very marked improvement in the general character of our almanacs. The first number of the 'Penny Cyclopædia' was issued by this society in 1833, and of its first volume 55,000 copies were sold.

The Working Men's Educational Union was founded in 1852, for the purpose of "assisting all persons desirous of imparting interesting and popular literary and scientific information imbued with a sound Christian spirit," whether by the delivery of lectures, the formation of libraries, or the promotion of mutual-instruction or other classes for adults. The agency of this society is to a very considerable extent gratuitous, and the lectures are mostly delivered in such suitable places as are obtainable free of cost.

From the *Dublin Tract Repository* there have been issued within the past eight years 34,000,000 of publications, including pamphlets and small books.

The Pure Literature Society was established in 1855, for promoting the extensive circulation of all such books, maps, prints, diagrams, and other publications as may be deemed good and useful by the managing committee; but the society itself abstains from publishing. Grants of well-selected books are made at half-price in aid of parochial and other libraries, to mechanics' institutions, working-men's societies, and for distribution to sailors, soldiers, emigrants, miners, and navvies.

Hawking or Colportage of carefully selected books and prints was systematically commenced in England in 1851, and within the last ten years much has been done in this way to promote the circulation of pure literature in the rural districts. Sixty-two local associations have been organized, and are united with the "Church of England Book-hawking Union," which employs about eighty book-hawkers, whose aggregate sale is now about £16,000 per annum.

Another society, designated the *British Colportage Association*, was established in 1860, with a view of carrying out the same object by agents not restricted to the sale of books and educational appliances, but who are expected to act also in a certain sense as missionaries.

The numerous publications specially used for instruction in the *Schools of the Poor* are mostly issued by one or other of the school societies, and no accurate estimate as to their numbers can be given.

A class of publications intended to impart a general knowledge of *Sanitary Science*, in its application to every-day life, has been lately introduced, and now forms an important branch of the instruction conveyed to the labouring-classes through the various agencies under review. The production and circulation of such publications is a main object of the *Ladies' Sanitary Association*, which has since its establishment in 1857, distributed 468,500 copies of small works, sold mostly at from 1*d.* to 2*d.* each. The issue of sanitary publications was commenced by Messrs. Jarrold & Sons about ten years since, under the designation of "Household Tracts," which are sold at 2*d.* each, and of these the number issued up to June last was 1,345,000. Of another class, entitled "Science for the Household," 125,000 copies have been circulated.

Publications promotive of temperance are circulated very extensively from the establishment of Mr. Tweedie, 337 Strand, and many other booksellers. One journal devoted to this cause has a circulation of 25,000 copies weekly. The 'British Workman,' issued at 1*d.*, and the 'Band of Hope Review,' at ½*d.* have now a circulation of about 250,000 copies each, with a well-merited increase.

From Mr. Peter Drummond's Tract and Book Depôt, at Stirling, N. B., have been issued since 1848, gratuitously and by sale, 33,600,000 tracts of 1 to 12 pages each.

Another publishing firm, that of Mr. John Cassell, issues from 25,000,000 to 30,000,000 annually of well-written penny publications, besides the 'Popular Educator,' the 'Illustrated History of England,' and the 'Illustrated Family Bible,' in weekly penny numbers, of which, up to the present time, 21,000,000 numbers have been printed.

To this greatly increased circulation of a pure and instructive cheap literature, and particularly to the extensive distribution of the Sacred Scriptures, the author feels justified in attributing, in no small degree, the striking change in the conduct of our manufacturing operatives, at the present time of severe privation and suffering, as compared with their riotous proceedings in days not very remote from the present; and he would trust that their conduct may prove instructive to some in other countries, who, exalted in authority, and knowing not the value of moral influence in governing a people, fetter the human mind, and incarcerate those who, having themselves experienced that the ways of true wisdom are pleasant, and her paths peace, would lead others to walk therein.

A Statistical Inquiry into the Prevalence of numerous Conditions affecting the Constitution in 1000 *Consumptive Persons. By* EDWARD SMITH, *M.D., LL.B., F.R.S., Assistant Physician to the Hospital for Consumption at Brompton, &c.*

The inquiry was made upon 600 male and 400 female patients at the Hospital for Consumption, Brompton, and was intended to show the influence of all the causes which are believed to modify the health.

The average age of the patients was 28·8 years. 30 per cent. had been born in London, 36 per cent. had lived chiefly in London, and 53 per cent. had lived in

London during the preceding 3 years. 8·8 per cent. could not read or write; and only 14·3 per cent. had been insufficiently nourished.

1. *Parental conditions.*—54 per cent. had lost the father, 46 per cent. the mother, and 28 per cent. both parents; in 25 per cent. only were both parents living. The average age of the parents at death was 50·8 years, with an increased duration of 4·7 years on the part of the fathers. The most frequent age at death was 35 to 55 years, whilst only 11 per cent. died under the age of 35, and some lived upwards of 95 years. 18 per cent. had experienced feeble health before the birth of the patient, and 34 per cent. throughout life; in 22·7 per cent. one or both parents had led unsteady lives. 21·1 per cent. of the parents had died of consumption, whilst in 2·8 per cent. the grand-parents, 23·3 per cent. the brothers or sisters, and 9·1 per cent. the uncles or aunts had died of the same disease. They had suffered from rheumatism in 22 per cent., from asthma in 9·4 per cent., from liver-disease and gout in 9 and 7·2 per cent., and from fevers, ague, insanity, and diabetes in 4 to 5 per cent. Presumed scrofulous affections were extremely rare. In only 6 cases was there consanguinity of the parents.

The age of the parents at the birth of the patients was, in half of the cases, from 25 years to 35 years, and in only 2 per cent. was it less than 20 years. The number of the children was very large, viz. an average of 7·5 to a family, and in some families there were 23 children. The patient was the first child in 20 per cent., and the first, second, and third child in half of all the cases. 40 per cent. of the parents' children had died.

2. *Personal Conditions.*—In only 23 per cent. were the patients under æt. 20, and a few were æt. 60. 24 per cent. had been feeble at birth, whilst 22 per cent. had suffered from feeble general health, and 17 per cent. from generally defective appetite. In 12·6 per cent. the lungs had been always delicate; 2·5 per cent. had been dry-nursed; 25·4 per cent. had perspired with unusual freedom; 25 per cent. had never worn flannel next the skin, and 55 per cent. had suffered from coldness of the extremities; 72·5 per cent. had an excitable temperament; 62·1 per cent. had medium brown or light-coloured hair, 74 per cent. had grey or blue eyes, 60 per cent. had florid complexion, and 46·7 per cent. had a fleshy habit.

16, 65·4, 60, and 41 per cent. had not had measles, scarlet fever, small pox, and hooping-cough in their order, and the frequency of any long-continued ill-effects from these diseases was insignificant; 12·8 per cent. had suffered from enlarged glands, and 4·5 per cent. from long-continued affection of the eyes, but otherwise the ordinary scrofulous disease scarcely existed. 16·7 per cent. had suffered from inflammation of the lungs, and 14·8 per cent. from rheumatism, whilst typhus fever and frequent diarrhœa had occurred in 8 per cent., ague in 5·6 per cent., and liver-disease in 4·3 per cent. of the cases.

The menses appeared at æt. 14 and 15 years in 36·4 per cent., and in 11 per cent. only was it before æt. 13. 43·5 per cent. were married, and of these 13 per cent. had not borne children. Their average age at the birth of the first child was æt. 20 to 25, and in only 9 per cent. were they under æt. 20. The number of children per family was 1 and 2 in 44 per cent., and 1, 2, and 3 in 55 per cent.; 38 per cent. of the children had died, and in 43 per cent. the general state of the health of the children was bad; abortions had occurred in 46·2 per cent. of the child-bearing married women.

29·6 per cent. of the males had led a bad life at some period, 24·5 per cent. had smoked tobacco, 19·3 per cent. of both sexes had submitted to late hours, and 22·2 per cent. had suffered much anxiety. In 70 per cent. some complaint was made as to the injurious influence of their occupations, as exposure, long hours, close and hot rooms, bending posture, dust, or fumes, &c.

The author then entered into a consideration of the question of hereditary transmission, and showed the relation of such an inquiry to the purposes of life assurance; but was of opinion, that as consumptives are a very mixed class of persons, and the causes of the disease most various, the only safeguard to life-offices was the careful examination of the chest of applicants by competent physicians.

On the Income Tax. By W. T. Thornton.

The object of this paper was to show, first, that every income-tax whatsoever must necessarily violate the just principles of taxation; and, secondly, that a uniform income-tax does so to a greater extent than there is any necessity for. Taking as the principles of taxation those laid down as such by Adam Smith, and adopted by Ricardo and John Stuart Mill, the writer undertook to prove that the least objectionable income-tax must needs infringe three of Adam Smith's four maxims. Instead of being levied at the time and in the manner most convenient to the contributor, an income-tax is levied at the most inconvenient time and in the most offensive manner. A man pays his customs or excise dues a little at a time, and chooses his own time for paying,—never, of course, volunteering to pay, except when he has wherewithal to pay. But the income-tax comes upon him both all at once and just at the very time when he is beset with his half-yearly bills, levying a pitiless percentage on his means of meeting them. It lays him, too, on the rack, endeavours to extort a confession from him, and leaves him no alternative but to criminate or to perjure himself. Then, the income-tax is levied most unequally. It is assessed, not, as Adam Smith says it should be, in proportion to a man's ability, but in proportion to his honesty. An income-tax must often be, to a certain extent, a matter of conscience. Those who have no conscience may partially evade it by lying; and thus it acts as a bounty upon lying, and a tax upon truth. The honest man bears the full burden; the dishonest goes comparatively free. This is a vice inherent in and inseparable from every income-tax whatsoever. There must always be this to counterbalance any virtues it may possess. True, it has the merit of raising a revenue more effectually than any other expedient, but at what cost does it do so? The mere pecuniary cost of its collection may perhaps be moderate as compared with that of the customs or excise, but money is not the sole element of cost. The income-tax is collected at the expense of the national honesty. It offers a powerful temptation to every commercial and every professional man to tell one deliberate falsehood, to commit one gross act of fraud, every year, and it is certain that a large majority of commercial and professional men yield to the temptation; for, from the last returns, it appears that there are, in Great Britain only 6066 persons in trades or professions honest enough to confess that they make more than £500 and less than £600 a year; only 6020 who confess to more than £1000 and less than £2000 a year; only 997 persons who confess to £5000 and less than £10,000. Since it cannot be supposed that people who cheat regularly once a year will cheat only once a year, or that, beginning with cheating government, they will end without cheating their customers, it is plain that the income-tax is undermining the national honesty, and consequently that commercial prosperity also of which national honesty is one of the bases. Although then an income-tax may possibly not *take* out of people's pockets a great deal more than is paid into the exchequer, it is calculated to *keep* out a great deal that would otherwise have entered.

Considering it to be thus apparent that every income-tax must necessarily be at variance with just principles, Mr. Thornton proceeded to argue that a uniform income-tax violates them to a needless extent. It does so by superadding to the inequality and injustice inseparable from every income-tax an inequality and injustice peculiar to itself. This is implied by its very name—a uniform income-tax, *i. e.* a tax levied at the same rate on all incomes. But, says Adam Smith, every one should pay taxes in proportion to his ability. His ability to do what? Obviously in proportion to his ability to pay taxes. But such ability by no means corresponds with income. To illustrate this point, Mr. Thornton supposed two persons, each with £1000 a year, but the one a bachelor, and the other a man with a family. Both have the same income, but their ability to bear taxation is very different; or, to use Ricardo's application of Adam Smith's principle, equal taxation requires from them very unequal sacrifices. Consequently, a tax assessed at the same rate on all incomes, without reference to the varying amount of claims on those incomes, is not assessed "in proportion to the respective abilities of the several contributors." Moreover the income-tax is the only tax at present in use amongst us which does affect incomes without regard to other claims upon them. A prudent family man, by living in a cheaper situation, by keeping only female servants, by walking on foot or riding only in cabs or omnibuses, by eschewing cigars, and drinking beer or spirits instead of wine, may always manage to pay a smaller percentage on his income, in the shape of assessed taxes, customs, and excise duties, than an unencumbered bachelor of equal income. It is the income-tax alone which falls with indiscriminating weight upon both, and which, regarding not the ability to pay taxes, but simply the amount of income, makes the same deduction from the £1000 by which a dozen persons are to be supported, as from the £1000 appropriated to the exclusive use of a single individual.

Here is one inequality incidental to a uniform income-tax. Another arises from the equal assessment of permanent and precarious incomes. Two persons, each of £1000 a year, but derived in the one case from landed, funded, or otherwise realized property, and in the other, from the profits of trade, the gains of a profession, or the salary of an office, have not the same means of paying taxes. The one may spend his £1000 a year for fifty years together, and at the end of that period his means of spending £1000 a year will be found undiminished. But if a merchant, or tradesman, or doctor, or lawyer, or railway secretary be silly enough to spend the whole of his £1000 a year, then if health fail, or business fail, he may suddenly find himself without a penny. Accordingly, he commonly puts by part of his income, and spends only the remainder; and the amount of that remainder is the measure of his ability to pay taxes, the amount therefore on which he ought to be taxed. In support of his view on this point, the writer quoted an expression of Adam Smith, to the effect that "every subject of a state should contribute to the support of the government in proportion to the revenue which he enjoys under the protection of the state;" from which he inferred that Smith intended to distinguish between the income which a man possesses and enjoys and that which he possesses and does not enjoy, remarking that a man enjoys only that part of his income which he spends, and that he no more enjoys what he saves for the benefit of his heirs than he enjoys the wine which is ripening in his cellar, and which may not be fit to drink till he is gathered to his fathers, or which may be kept till it spoils and may never be drank at all, just as money that is invested may not be accumulating for the benefit of the actual owner, and perhaps may not be accumulating at all, but may be dwindling away to nothing in the shape of railway shares. Mr. Thornton proceeded to remark that, among the many faults of an income-tax, there is only one which can be remedied. The tax is in most respects incurably bad. Nothing can prevent its being a discouragement to honesty and a bounty upon fraud, or from being collected at the expense of national probity, or from pressing with equal weight on single and married men of the same income, notwithstanding their unequal ability to bear the weight. One of its iniquities, however, is partially remediable. It might be prevented from pressing equally on permanent and precarious incomes, in the manner proposed by Mr. Mill, viz. by exempting from taxation that proportion of a precarious income which, taking the average of cases, its recipient would be bound in prudence to save.

The remainder of the paper was occupied with an examination of objections to Mr. Mill's suggestion. It has been urged that there is often a great difference between what a man ought to save and what he does save; and it has been asked, what could be more monstrous than to extend exemption to a spendthrift, who, being bound in prudence to lay by, say, a fourth of his income, thinks proper to spend all, and to save nothing? What could be more monstrous than to confer the reward assigned for the performance of a particular duty to one who had culpably neglected to perform that duty? In Mr. Thornton's opinion it is more monstrous still to withhold the reward from those who have performed the duty. In a country in which economists must be to spendthrifts as 100 to 1, it would, he thinks, be better that one spendthrift should obtain an exemption which he does not deserve, rather than that a hundred economists should be denied the exemption they do deserve.

Again, it has been urged that to assess precarious at a lower rate than permanent incomes, on the avowed ground, too, that the former belong to a poorer class of men, would be to tax the poor at a lower rate than the rich—a measure subversive of security of property. If, however, a reduced rate has been proposed for precarious incomes, it has been on the supposition that whatever rate were adopted would be assessed on the whole income. But to assess the whole of a precarious and the whole of a permanent income at the same rate would be to disregard their relative ability to bear taxation. If only that part of an income be taxed on which depends ability to pay, no one will object to the same rate being applied to all incomes. It is only because injustice is committed by taxing the whole income that an attempt is made to repair the injustice by demanding that a lower rate be imposed than would be proper if only part were taxed.

A third objection to Mr. Mill's suggestion is the opposite of the second. It has been said that to exempt savings would be to favour the rich at the expense of the poor, inasmuch as it is by the comparatively rich that the greater part of savings are made. To this Mr. Thornton answers, that if the rich pay on all they spend, and are exempted only on what they save, they obtain the exemption only on that part of their income with respect to which they abdicate the advantage of riches, not consuming it themselves, but making it over to be consumed by the poor. Moreover, if they pay on all they spend, they pay on all they enjoy; and the principle that every man should pay on what he enjoys, whether the sum be great or small, is fully carried out.

On Expectation of Life.

By Charles M. Willich, *Actuary, University Life Assurance Society.*

The author showed that the following *hypothesis* agrees very nearly with Dr. Farr's English Life Table, which was obtained from Returns made by every parish in England and Wales.

$$\text{If } a = \text{age in years,}$$
$$\text{then } \tfrac{2}{3}\,(80 - a) = \text{expectation.}$$

Also, that by an extension of the *hypothesis* we obtain the expectation of life closely agreeing with the result of the laborious investigation made by the late Mr. Finlaison as to the duration of the lives of female Government annuitants.

$$\text{If } a = \text{age in years,}$$
$$\text{then } \tfrac{2}{3}\,(86 - a) = \text{expectation.}$$

MECHANICAL SCIENCE.

Address of William Fairbairn, *Esq., LL.D., F.R.S., President of the Section.*

Every succeeding year presents to our notice some new feature of construction, or some new application of science to the useful arts. Last year we had to record several new discoveries in chemical as well as mechanical science; and this year is fruitful of machinery and the industrial developments, as exhibited in the courts of the International Exhibition. It is not my intention to occupy your time with a history of these Exhibitions, but I may be permitted to notice some of the most interesting objects, and some of the ingenious contrivances which we are called upon to witness, and which do honour to the age in which we live. Before I venture on a description of these objects, I must, however, crave your indulgence whilst I endeavour to notice some of the more important improvements which have taken place in mechanical science during some of the past years.

It may be stated that there is no period of the past history of science so fruitful in discoveries as the present century. Within the last fifty years we are enabled to enumerate the application of steam as a motive power to every description of manufacture, as also to navigation, locomotion, and agriculture. At the close of the eighteenth century the power of steam and its now almost universal application was, with the exception of a few engines by Boulton and Watt, comparatively unknown. Now it is the handmaid of all work, from our domestic requirements to the ocean-steamer of a thousand horses' power. This we may consider as the present state of steam and the steam-engine, and we have only to compare the small but beautiful construction of engines for private and domestic use, as seen in the Exhibition of this year, with those which propel our fleets, drain our mines, and move with clockwork precision the innumerable machines of our manufactories. To these we may add the use of steam to locomotion, and we realize the law of heat reciprocally convertible into mechanical force, or the dynamic theory of work done, in the energy of nearly a thousand horses' power, at fifty miles an hour. How wonderful and yet how effective are the powers of this comparatively small machine! It is perfectly docile, and obeys the hand of its director with almost mathematical precision, and by the touch of a simple lever it regulates its movements to the nicety of an inch, or it bounds forward with a momentum, regardless of time or distance, and careers on its iron track like a dream of the Arabian Nights. In fact, we may almost regard them as realized, when we consider the smallness of the space and the organisms by which these wonderful results are attained. Apart from the flight of fancy, we arrive at the conclusion that these are facts already accomplished with a degree of certainty that ceases to be wonderful, except only to the uninitiated, who stares at what he is unable to comprehend. The general principles of the steam-engine and the locomotive are, however, easily acquired; and in this age of steam it should, in my opinion, form a separate branch of education for the benefit of both sexes, to whom it would be highly advantageous. It is a branch of knowledge of deep importance to the present and rising generation; and as steam and its application to the varied purposes of civilized life becomes every day more apparent, a knowledge of its powers and properties is much wanted, and ought not to be neglected.

I am the more desirous that instruction of this kind should be imparted to the rising generation in our public schools, as it would lead to practical acquaintance with instruments and machines in daily use, and would familiarize the more intelligent classes with objects on which, at the present day, we almost exclusively depend for the comforts and enjoyments of life. I do not mean that we should make scholars engineers; but they ought to be taught the general principles of the arts, in order to appreciate their value and to apply them to the useful purposes by which we are surrounded. It is by the acquisition of this knowledge that we shall overcome ignorance, so often fatal in the use of steam, and not unfrequently attended with danger to life and property. We might quote numerous examples of fatal boiler explosions and other casualties arising from this cause; and this want of knowledge is not only productive of danger, but it leaves important matters to be directed by the hands of incompetency, instead of being guided by the arm of intelligence. The introduction of steam and its application to such a variety of purposes was shortly followed by that of gas, and this brilliant discovery we owe to the untutored mind of one of our first working mechanics, William Murdock of Soho, the assistant and contemporary of Watt. Mr. Murdock lighted up his own house and Soho about the year 1802 or 1803, and in 1804 gas was first applied to light Messrs. Philip and Lee's cotton-mills at Manchester. For some years it made little or no progress, but it was, in 1814, employed for lighting the streets of towns; and we are, therefore, indebted to William Murdock and carburetted hydrogen for the enjoyment of a pure and brilliant light in our streets and public buildings, and in almost every house and town in the empire.

Next to gas came steam-navigation, railways, and locomotion, and subsequently the electric telegraph. I will not, however, tire you with any detailed notice of these discoveries, however important they may be in a scientific point of view, but simply advert to those departments of science with which the members of this Section are more immediately interested. In taking even a cursory view of the machinery of the two annexes of the International Exhibition, we cannot be otherwise than struck with the multiplicity of the objects, the perfection of the execution, and the accuracy of the tools, together with the numerous devices by which these are attained. A very casual glance at this Exhibition when compared with that of 1851, and that of Paris in 1855, shows with what intensity and alacrity the public mind has been at work since the people of all nations were first called upon to compete with each other in the peaceful rivalry of mechanical art.

Taking the Exhibition as a whole, there is no very great nor very important discovery in mechanical science; but there is a great deal to be seen of a character both interesting and instructive. In land steam-engines there is nothing particularly attractive, if we except the growing importance of the horizontal, which is rapidly supplanting that of the beam or vertical engine. To the horizontal system may be applied economy in the first cost, and nearly equal efficiency in its application to mills and for manufacturing purposes. Another important feature in these engines is their smooth and noiseless motion, their compact form, and the facility with which they can be applied as helps or assistants to those of larger dimensions. They are, moreover, executed with a degree of finish and accuracy of workmanship which cannot easily be surpassed.

In the agricultural department the same observations apply to this description of engine, where it is extensively used on a smaller scale. They are equally well made, and the country at large are chiefly indebted to our agricultural engineers for many ingenious contrivances, and for their successful application, not exclusively to the farm, but to many other useful purposes in the economy of rural life.

From the motive power employed in our manufactories and its adaptation to agriculture let us glance at the beautiful execution, compact form, and colossal dimensions of our marine engines, and we shall find, in combination, simplicity of form, concentration of power, and precision of action never before equalled in this or any other country. In this department of construction we are without rivals, and it is a source of pride that this country, as the first maritime nation in the world, should stand preeminently first as the leader of naval propulsion.

In locomotive as in marine constructions we are not behind, if we are not in advance of other nations, although it must be admitted that several splendid specimens of engines from France and Germany are exhibited by some of the best makers of those countries. There is, however, this distinction between the Continental locomotives and those of home manufacture, and that is, in this country there is greater simplicity and design, greater compactness of form, and clearer conceptions in working out the details of the parts. These operations, when carefully executed to standard gauges, render each part of an engine a facsimile of its fellow; and hence follows the perfection of a system where every part is a repetition of a whole series of parts, and, in so far as accuracy is concerned, it is a great improvement on the old system of construction.

The other parts of the Exhibition are well entitled to a careful inspection. In minerals and raw material the collections are numerous and valuable to an extent never before witnessed in any Exhibition; and the articles, fuel and ores, will be found highly instructive. The machinery for pumping, winding, and crushing is upon a scale sufficiently large and comprehensive to engage the attention of the mechanic and miner, and it is only to be regretted that in every case competent persons are not in attendance fully prepared to explain and initiate the inexperienced student in the principles of the workings, and the cases of instruments so neatly classified and spread before him for instruction.

In the machinery department, although there is nothing that strikes the observer at first sight as new, yet there are many useful improvements calculated to economize labour and facilitate the operations of spinning and weaving; and in tool-making there never was at any former period so many hands and heads at work as on the occasion pending the opening of the Exhibition. Some of the tools, such as the turning-, boring-, planing-, and slotting-machines, are of a very high order; and the tool-machinery for the manufacture of fire-arms, shells, rockets, &c., is of that character as to render the whole operations, however minute, perfectly automatic or self-acting, with an accuracy of repetition that leaves the article, when finished, identical with every other article from the same machine. Such, in fact, is the perfection of the tool-system as it now exists, that in almost every case we may calculate on a degree of exactitude that admits of no deviation beyond a thousandth part of an inch.

Amongst the many interesting mechanical objects exhibited in the two annexes may be noticed as original, the spool-machine, for the winding of sewing-thread on bobbins, the machine for making paper bags (invented by a pupil of my own), the saw-riband machine, and others of great merit as regards ingenuity of contrivance and adaptation of design. In manufactures, in design, and in constructive art, there is everything that could be desired in the shape of competitive skill, and, without viewing the success of the Great Exhibition of this year in a pecuniary point of view, we may safely attribute its great success to the interesting and instructive character of the objects submitted to public inspection.

Irrespective of the Exhibition, with its invaluable and highly finished specimens

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we have briefly to notice some of the improvements and changes that have taken place in the construction of ordnance and the art of defence, and to chronicle some of the most important results which have placed the whole of our naval and military armaments in a state of transition. It is now well understood that His Majesty the Emperor of the French was the first to apply iron plates as a defence to the sides of ships, and that ships of war protected with a given thickness of plate 4½ inches were invulnerable to shot or shell. For a considerable length of time this opinion was prevalent, and was acted upon both in this country, France, and America. The experiments instituted by the Admiralty and War Office have, to a great extent, dispelled these notions; and it has been proved that a smooth-bored Armstrong gun, with a 150-lb. spherical shot, can pierce a 4½-inch-thick plate and 18 inches of teak. In fact, it has been proved by experiment that no vessel yet constructed is able to carry armour-plates of sufficient thickness to resist such powerful ordnance as has been brought against them.

Every effort has been made on the part of the Government to determine experimentally the properties of iron best calculated to resist shot, and the greatest possible care has been observed, both in a chemical and mechanical point of view, to secure the very best description of iron for that purpose. All these facts have been ascertained, as also the penetrating powers of different descriptions of ordnance as compared with the thickness of the plates to be pierced. In this position the balance of force to the resistance of the plate was in favour of the gun, but with this qualification, that the gun had to sustain an explosive force of powder equivalent to one-third the weight of the shot, a charge which the gun was unable to bear. Under ordinary circumstances, with the usual charge of one-eighth the weight of the shot, it might reasonably be inferred that the balance was on the side of the plate, and that guns of such heavy calibre were insufficient in strength to sustain these tremendous charges of powder. Again, it must be borne in mind that these results were only produced at certain distances, and under certain conditions of heavy charges of powder and a short range of 200 yards.

The inquiry was thus hanging on the balance, when it was determined to ascertain the effect of the large Horsfall gun of 22 tons weight with a charge of 75 lbs. of powder and a 300-lb. shot, against a target representing the 'Warrior,' with her 18 inches of teak and 4½ inches of iron. The result of this experiment was the penetration of the mass, with a huge opening in the side of the target upwards of 2 feet in diameter. This experiment is probably not calculated to apply to ships of war carrying ordnance of such immense weight, but it is greatly in favour of forts, where an enemy's vessel may be struck at a distance of 1000 yards.

Passing from the Horsfall gun, we now come to the last and most important experiments with the Whitworth gun: the first was a 12-pounder field-gun, and the second a 70-pounder naval gun; both of the guns were rifled. These experiments are very instructive, and I probably could not do better than quote from the 'Times,' of September 18th, a statement of the effect produced by these guns:—

"It will, perhaps, be remembered that a decided difference was established very early in the controversy between the penetrating powers of solid shot and those of shell. Solid shot at one time failed, and at another time succeeded, against armour-plates, according to the modified conditions of the experiments; but shells failed absolutely and invariably. No shell could ever be driven through even a moderately thick plate of iron, and it was concluded, therefore, that this, the most dangerous and dreaded species of missile, could undoubtedly be kept out of a ship by a thin casing of armour.

"Accordingly, as a reduction of a ship's armour to the least possible weight was of great consequence, especially in small vessels, gunboats and other craft of the like description have been built in some countries with 2½-inch or 2-inch armour-plates, and considered effectually shell-proof. On Tuesday, however, Mr. Whitworth entered the field with two of his pieces, for the service of which he had specially prepared some flat-fronted, hardened shells. The 12-pounder, at 200 yards, presently sent these shells through a 2-inch plate backed by a foot of timber; from which simple piece of evidence the conclusion is inevitable, that vessels protected to that extent only are shell-proof no longer.

"But in the trial of the 70-pounder an additional result was obtained. It has been suggested that if, instead of employing a given thickness of iron in one solid piece, the armour of a ship were divided into two plates, each of half that thickness, and these plates were separated by a certain space from each other, the resisting power of the structure might be much increased. The theory was that the first plate, though it would doubtless be pierced, would so deaden the force of the shot, that the second plate would repel it; and, indeed, as regards solid shot, the question remains still undecided. With respect to shell, however, or rather Mr. Whitworth's shells, we are not left in doubt even on this point. The 70-pounder was trained against a target constructed on this principle of a double side. A strong oak frame, armed with 4-inch plates, was attached to a second plated to the depth of 2 inches, an interval of two or three feet being left between them. The shell from this gun, fired with 12 lbs. of powder only, pierced the outer side of the target completely, oak and iron together, after which it burst inside the frame and shattered it to pieces."

From this statement we learn, that 4 inches of solid iron and 9 inches of wood are no protection against shells discharged from a moderately sized gun, and that no gunboat, such as those on the American waters, could prevent the entrance of these dreaded and destructive missiles. In point of fact, Mr. Whitworth, with a rifled gun lighter than the 68-pounder, could destroy them by his steel-hardened shells at a distance of 1500 to 2000 yards.

Since the above was written another experiment has been made with a still larger gun, rifled on Mr. Whitworth's hexagonal principle. This gun was of large calibre, 120-pounder, at a distance of 600 yards, and the results seem to prove that the side of a vessel like the 'Warrior' is no longer shell-proof. In these experiments 130-lb. solid shot, with a charge of 23 lbs. of powder, went right through the 4-inch armour-plate and lodged in the teak backing behind. A shell of the same weight, and a charge of 25 lbs. of powder, also penetrated the armour-plate and exploded, tearing the wood backing, and lodged on the opposite side.

From these more recent experiments we may infer that the victory is on the side of the gun, and that it may be difficult, under such fearful odds, to construct ships of sufficient power to prevent their destruction by the entrance of shells. Other experiments are, however, in progress, and means may yet be adopted to solve the question of armour-ships *versus* shot and shell.

On the Importance of Economizing Fuel in Iron-plated Ships. By E. E. Allen.

Iron-plated ships, to be efficient, ought to be able to carry coals for fourteen days; but in consequence of the weight of the armour, and the present mode of generating and using the steam, only coals enough for seven days can be carried. In future wars, despatch in going to the seat of war, and high speed in manœuvring, will be necessary; therefore much fuel must be used; hence the desirability of studying how to economize fuel. The deficiency of boiler-power in the Royal Navy is too well known. Modern inventions have increased the displacement of ships: thus the armour, coals, and machinery are about equal in weight; and 1000 horse-power will consume 200 tons of coal a day, under full steam, say at ten knots per hour; but the necessary power for increasing the speed from ten to twelve knots demands double the fuel; and if the speed be increased to sixteen knots, the amount of fuel must be quadrupled. Some of our new war-ships only move at 9½ knots an hour, whereas it is generally allowed they should make 15 knots; 5000 miles ought to be steamed without re-coaling, but only one-third of that distance can be accomplished. As a proof that the boilers are too small, it may be affirmed that none of the ships in the Royal Navy can work full steam, and keep the throttle-valves open, for more than a few hours at a time. Six-hundred horse-power boilers should be used where only 400 horse-power boilers are now used. Coal is the only item in which weight can be saved. The merchant vessels only consume half the coals (for ships of the same size) of those in the Royal Navy. Cornish engines consume 2¼ pounds of coal per horse-power per hour; 2½ pounds ought to be the limit in marine engines; but 6 pounds are generally used in the Royal Navy. He proposed the following methods for economizing fuel:—To proportion the boilers to the steam required; to increase the capacity of the cylinders, but not the length of the stroke;

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to superheat the steam; to jacket the cylinders to warm the injection water; to work the steam expansively by having two cylinders, a small one at the back of the large one, or concentrically within the large one, and to let the steam into the small cylinder first. Although he recommended this to our Admiralty in 1855, no notice was taken of it. The Swedish Government have adopted it in their new gun-boats, and it obtained a medal at the present Exhibition. By these arrangements for economy, and with better-designed engines, 17,000 tons of coal per day might be saved throughout our fleet; but now, after steaming 2000 miles, the ships have to creep into port, under canvas, to be re-coaled. 40 per cent. of power might be added, and therefore a greater speed of one-and-a-half knot per hour obtained, without greater displacement; and 14 tons per horse-power per annum, or a million tons of coals per annum, for the whole fleet might be saved.

On Artificial Stones. By Professor D. T. Ansted, *M.A.*

In this paper the author described the various materials and contrivances used for the purpose of replacing stone where natural stone could not be advantageously procured. He described, in succession, terra cottas, cements, and siliceous stones, pointing out the character, properties, uses, advantages, and disadvantages of each. He alluded to experiments made in the laboratory on the various methods suggested for preserving stone by a Section of the Committee recently appointed by the Board of Works in reference to the Palace of Westminster; Dr. Hofmann, Dr. Frankland, Mr. Abel, and the author being members of it. During their investigations a remarkable material was submitted by Mr. Ransome for their consideration, and its discovery arose out of Ransome's method of preserving stone by effecting a deposit of silicate of lime within the substances of the absorbent stone, saturating the surface with a solution of silicate of soda, and then applying a solution of chloride of calcium; thus producing a rapid double decomposition, leaving an insoluble silicate of lime within the stone, and a soluble chloride of sodium, which could afterwards be removed by washing. To prove this, Mr. Ransome made small blocks of sand in moulds by means of silicate of soda, and then dipped them in chloride of calcium. The result was the formation, almost instantaneously, of a perfectly compact, hard, and, to all appearance, a perfectly durable solid. Mr. Ransome at once adopted the process for the formation of an artificial stone which, the author of the paper considered, would combine the advantages, and avoid some of the disadvantages, of other artificial stones. Experience, however, can alone be the test of its durability. A specimen weighing two tons was shown in the International Exhibition, and the substance is used in the stations of the Metropolitan Railway. It is cheap, and can be made, on the spot, of almost any rubbish or material, and of any form or size. Experiments made by Mr. Ransome show that, as compared with Portland stone or Caen stone, a bar with section 4 inches square and 8 inches long, suspended midway between supports, sustained 2122 lbs., while similar bars of Portland and Caen stone broke respectively with 750 lbs. and 780 lbs. The adhesion of the stone was shown by weights suspended from a piece prepared to expose a sectional area of 5½ inches. Caen stone separated at 768 lbs.; Bath, at 796 lbs.; Portland, at 1104 lbs.; Elland Edge, at 1874 lbs.; Ransome's, at 1980 lbs. A cube of 4 inches of Ransome's stone sustained 30 tons.

Unsinkable Ships.

By Charles Atherton, *late Chief Engineer in H.M. Dockyard, Woolwich.*

The author observes that competitive rivalry in the construction of ships of war with a view to their being "invulnerable," and in the construction of ordnance with a view to its being effective for penetrating the build even of armoured ships, appears, from the experiments which have been carried on at Shoeburyness, to be a question involving unlimited expenditure in possibly abortive ship-building, the result of which rivalry between ordnance and iron plating, being dependent on future invention, does not admit of present definite solution.

Nevertheless the principle of "invulnerability" in the construction of ships of war by the agency of iron plating having been originated and adopted by France

present the most effective system of naval construction, though admitted to be imperfect, there has arisen internationally a necessity for its adoption until it shall be met or superseded by some other device; and the object of the author, by this paper, is to bring before the notice of the British Association for the Advancement of Science the question, which has been otherwise publicly agitated by him, whether the principle of "invulnerability," as based on "armour-plating," may not be superseded by the principle of "unsinkability," as based on the principle of constructing ships with such a mass of uninflammable materials of a specific gravity less than that of water as shall support the hull and its entire load, and float, however perforated by shot laterally through the sides of the ship, or vertically through the deck and bottom of the vessel by the still more formidable effect of an improved mortar-practice pitching shells of great weight with an infallible precision at short range, or even still float in parts when severed by the concussion of a hostile ram.

Though the vessel may thus be "unsinkable," it is not professed or anticipated by the author that war would be prosecuted without the sacrifice of blood; for though the proposed construction of shipping would be well adapted for protecting the crews of ships from small arms, still the cannon or the mortar would take effect. The chief point on which the principle of "unsinkable ships" is put forward by the author as claiming consideration is that, by the adoption of this principle, the whole crew of a ship would not be simultaneously drowned through the effective application of a single shot, shell, or ram-stroke, as might be the case with armoured ships, seeing that the direct fire of artillery is still paramount, and the mortar practice above referred to has not yet been tried.

A further advantage consequent on adopting the principle of "unsinkability" would be that it does not necessitate the construction of ships of such large size as is required for carrying out the principle of "invulnerability" by armour-plating. Also by avoiding top-weight, by which armour-plated ships are so much encumbered, many difficulties in the prosecution of naval architecture are obviated. It is therefore conceived that this principle of "unsinkability" would be well adapted for gun-boats and mortar-vessels destined to act in cooperation with each other in assailing larger vessels at close quarters, or doing service in shoal waters, such vessels receiving their stores from high-speed steamers of ordinary build acting as store and hospital and barrack ships, to be kept out of harm's way. Also the principle of unsinkability would be well adapted for troop ships and the safe conveyance of valuable cargoes and treasure.

The details of construction of the "unsinkable ship," as respects the disposal of its unsinkable materials, will be dependent on the purpose for which the ship may be especially intended. For example, the whole mass of material on which the ship depends for its unsinkability may be in a solid mass, with the whole of its hold accommodation above the deep-draught water-level; or the vessel may have a hold below the level of the load water-line, provided that the required mass of buoyant material be otherwise disposed of, constituting the sides or ends and bottom and decks of the vessel. Of course such a vessel with a hold below the load-line level may become water-logged, and, if a steamer, disabled; but still such a vessel would sail, and the crew would be alive to do good service from her deck; at all events her whole crew could not be simultaneously sent to the bottom, which is the great catastrophe intended to be obviated by the principle of unsinkable ships—a catastrophe to which armour-plated ships, though bulkheaded, will be liable if artillery or mortar practice become paramount.

The required brevity of this abstract does not admit of the details of calculation and of construction for the production of "unsinkable ships" of given capabilities being here entered upon; such an exposition, to be complete, would be elaborate, and may engage the future attention of the author.

On Coryton's *Vertical-Wave-Line Ships, Self-Reefing Sails, and Guide-Propeller. By* John Coryton, *of Lincoln's Inn, Barrister-at-Law.*

The object of the inventor has been to produce a form of vessel which shall combine the weatherly qualities of a clipper ship, with the advantages of increased speed when going free, and greater safety when scudding before a gale, riding at sea anchor, or becoming suddenly unmanageable through loss of masts, damage to her machinery, &c.

This object is attained by a revolution in the tactics of sailing, as well as in a change of form. When close-hauled, or steaming head to wind, the vessel goes—to use the parlance applicable to the present form of ships—head foremost; when sailing or steaming off the wind, she goes, so to speak, stern foremost. In still water the vessel proceeds always on the latter plan. The terms stem, bow, and stern being obviously unsuited to vessels of the proposed form, the inventor substitutes for them the "weather end" and "lee end" respectively.

Novel as the general idea pervading this invention may appear, the deviation in point of form of a Vertical-Wave-Line vessel from the type of ships at present existing is very slight. Taking as a standard a fast clipper schooner of the latest build with a "tumble home" bow, fine entry lines, beam carried right aft to the taffrail, and a flat counter, something very like the proposed form will be obtained by cutting away the entire after-keel almost from the fore-foot; the "weather end" thus becoming (approximately) a vertical wedge, and the "lee end" (approximately also) a horizontal wedge. Provided these forms are preserved, the intermediate work is of little consequence, and may be constructed simply with regard to the ordinary rules of carpentering—a point of economy which those practically acquainted with ship-building will not fail to appreciate. "It seems," is the observation of M. Vial de Clairbois in his 'Architecture Navale' (p. 22), "that naval architects have hitherto *affected* to avoid straight lines, although geometrically they have the advantage of simplicity over all others." By a coincidence which may appear almost accidental, it will be found that at two points of the vessel constructed on the new principle (and in these, in the larger class of vessels, it is proposed to bulk-head them), sections made by planes slightly out of the perpendicular approach very nearly the catenary—a self-supporting curve. The inventor proposes to construct his vessels of laminated iron up to the water-line, and to make the works above, for the convenience of rough repairs, of wood. By making the iron planks taper towards the ends, and decrease in number as they are placed higher on the ship's side, the greatest strength of the vessel may be placed with almost mathematical accuracy at the point exposed to the greatest strain.

The advantages of this system, besides economy and strength, may be shortly stated thus:—*Safety*. If disabled, instead of rolling in the trough of the sea like the 'Great Eastern' on a recent occasion, a Vertical-Wave-Line ship flies head to wind at once, and remains so as long as she can hold together. In boats of this construction "broaching-to" (the fertile source of disaster in passing through surfs or being beached) is entirely avoided, the boat being always kept by the action of the water in the only position compatible with safety. The same peculiarity of form, offering a *maximum* deflection to an impinging body, renders Vertical-Wave-Line ships admirably adapted for the purposes of naval warfare. A model of a Shield Ship on this principle was exhibited at the International Exhibition during the present year.

Stability.—Vertical-Wave-Line ships will never accumulate rolling motion. From the form of the immersed body, if lateral disturbance take place, the axis of rotation changes with such rapidity as to render it all but impossible that any subsequent impact of wind or sea can have the effect of increasing, and almost certain that each such impact will actually neutralize, the existing momentum. It is this peculiarity, coupled with its safety in exposed situations, that has induced the inventor to suggest this form as suitable for the establishment of a system of Fairway Lighting in the English and Irish Channels, plans and models of which were recently exhibited at the International Exhibition of 1862.

In respect of *Speed*, a very remarkable phenomenon presents itself, in the case of Vertical-Wave-Line ships sailing off the wind or steaming free, working consequently "lee end" foremost. *For every increase of speed there is a decrease of draught*. That there is a limit to the truth of this is of course evident; but as a totally new problem, the inventor anticipates from its investigation very extraordinary results. From the absence of keel at the lee end, the vessel steers of course with great *handiness*, and with the Guide-Propeller can be made to turn in her own length.

The revolution in tactics alluded to above, rendered of course the ordinary system of rigging useless, and the inventor has consequently devised the system of Self-reefing traversing sails (also lately exhibited at the International Exhibition). The masts, which are T-shaped, are supported by revolving shears, and the sails are fixed on spars rigidly attached to the masts. The mast is thus inclined to the wind, or "rakes," to use the ordinary term, whether the vessel be by the wind or going free—an arrangement which, for the same vertical height of masts, gives a greater and far more efficient spread of canvas than can be produced by any of the systems now in use. On a smart breeze springing up, the sails reef themselves to the compass requisite for the vessel's progress; and, as the gale freshens, reef after reef is taken in, until, when it is at its height, her sails will be found close-reefed without the employment of a single hand. If the ship be clear of the land, her sails can be furled, her helm left, and the ship will ride the gale out head to wind.

Ships and boats on this principle can, of course, equally with any others, be propelled by steam or other power. In his Atmospheric Guide-Propeller (exhibited also in 1851 (Class VIII. 82) and 1862 (Class XII. 2746)), the inventor has endeavoured to introduce a great simplification into ship propulsion, by combining the processes of steering and propelling. The plan consists in pumping a current of air through tubes which are led outside the vessel into the water, this current being capable of the nicest regulation and change of direction by means of valves. Water may be used instead of air, and is recommended for boats, in which, it may be observed, oars are entirely dispensed with, and propulsion is effected by hauling on an endless rope.

The last point is *Ventilation*, and for the appreciation of the advantages of the new system in this respect it is almost necessary to refer to models. In the Exhibition of 1862 a model was shown, made to a scale, and intended to test the relative merits of a ship on this system and the 'Great Eastern.' The dimensions of the vessel on the Vertical-Wave-Line system of equal tonnage were, length 432 feet (as against 700 in the case of the 'Great Eastern'), breadth 108 feet, depth 76 feet.

Models and drawings illustrative of the construction and propulsion of Vertical-Wave-Line ships may be seen at the Naval Museum of the Royal United Service Institution, Middle Scotland Yard, and at the Museum of the Commissioners of Patents, South Kensington.

A New Marine Boiler for generating Steam of High Pressure.

By Dr. F. GRIMALDI.

The boiler was a cylindrical tubular boiler, with certain arrangements of radial tubes for taking up and conveying the steam, and made to rotate slowly in the furnace on its axis. The advantages claimed were freedom from priming, smallness of space occupied, superheating the steam, and economy of fuel.

On the Prevention of Railway Accidents. By J. SEWELL.

The author considered that the main cause of accidents was the want of punctuality in the trains; and that this arose mainly from the overloading of them, which rendered it impossible that they could keep time. Engines were made to perform certain work, and draw certain loads, and if these were exceeded it was impossible that time could be kept. This was a matter that the public could not ascertain for themselves, and he therefore advocated the importance of having engines licensed, like boats, omnibuses, &c., by Government, to draw certain loads; and a statement giving that information should be placed conspicuously on the engine. This would prevent the overloading, as it would be in the power of every passenger to see whether the power of the engine was duly apportioned to the carriages it had to draw.

On the Failure of the Sluice in Fens, and on the Means of securing such Sluices against a similar Contingency. By W. THOROLD, *M.I.C.E.*

The author described the circumstances attending the failure of the sluice, and pointed out by a diagram that, in his opinion, the mode of preventing such an accident in future was the employment of double sluices, one behind the other, the water between the two being always kept locked in, at a mean height between the water in the drain and that on the sea-side, during the time the sea doors are closed by the tide; by this mode, the pressure of the highest tide, on each set of doors, will be only *one-fourth* of that on the single set of doors, on the fallen sluice, at the time of the disaster. Hence its undoubted safety.

On the Merits of Wooden and Iron Ships, with regard to cost of repairs and security for life. By L. WILLIAMSON.

The author called attention, in particular, to an iron ship, the 'Santiago,' which met with a collision, the consequences of which would have been absolute destruction of the vessel had she been of wood; whereas, being of iron and having watertight compartments, the vessel was able to pursue her voyage, and was repaired at the cost of a few hundred pounds, instead of several thousands which would have been necessary had she been made of wood and could have been preserved from foundering.

Oblate Projectiles with Cycloidal Rotation, contrasted with Cylindro-ogival Projectiles having Helical or Rifle Rotation. By R. W. WOOLLCOMBE.

The object of this paper was further to discuss the views of the author given in a paper read before the Royal Society in March last (1862), entitled, "An Account of some Experiments with Excentric Oblate Bodies and Discs as Projectiles," and to show the result of further experiments. Rifled cannon, it appears, cannot project heavy elongated shot with high initial velocity; and, except with the Whitworth flat-headed shot, the penetration of iron plates can only be effected by means of a high velocity. The author considers that however well the helical or rifle method with cylindrical elongated shot may answer for small arms, yet that, when we wish to project great weights with great and sustained velocities, we shall succeed better if our mechanical arrangements are less antagonistic than the rifle principle to the great laws of nature, as exhibited in the form, method of rotation, and translation of the great natural projectiles, the planets. None of these are prolate bodies projected with helical rotation about their longest diameters and in the direction of such axis. The author states that he has found it practicable to project a body that, instead of being prolate, is more or less oblate,—that, instead of having helical rotation at the *expense* of translation, has cycloidal rotation in *aid* of translation. A projectile, having a circular periphery in the line of motion in the gun, leaves the bore as a common round shot, and has the additional security for high initial velocity of windage less than for round shot of similar weight. The terminal velocity is also provided for by the oblateness, and by the axis of rotation being always transverse to, and not in the plane of, the trajectory. The gun has a similar transverse section to that of the projectile, the bore being straight and smooth. The projectile is a disk, and it should be *slightly* excentric to make it rotate—so slight as to be *little more* than the inevitable excentricity of every spherical projectile. The author then gave the results of some actual experiments with a gun and projectiles made on this principle. The gun was 20¼ inches long; the calibre, long diameter 1⅞ inch, and short diameter ¾ inch. The shot weighed nearly 8 ounces, with a charge of 2¼ ounces, or three-fifths the weight of the shot; the penetration at 25 yards from an oak target was a mean of 11 inches, reckoning to the near side of the disk, and to the far side nearly 18 inches.

The initial velocity, measured by Havez's electro-ballistic apparatus, was 1487 feet per second. A comparison was made with a small brass gun, length of bore 34·625 inches, or nearly double the length of the author's gun in calibres. The mean calibre of the brass gun was 1·6 inch, the mean diameter of the round shot was 1·43 inch; and this gun, fired with a proportionate charge of powder, showed that the disk gun gave more than double the penetration of the brass gun, and an initial velocity of 1487 to 1091 of the latter. He thought that these remarkable experiments showed that the subject was worthy of further consideration.

APPENDIX.

On the Solution of the Linear Equation of Finite Differences in its most General Form. By Prof. SYLVESTER, *F.R.S.*

The author exhibited (and illustrated with examples) a simple and readily applied method of obtaining the general term (and consequently the complete solution) of an equation of finite differences with any number of independent variables; a question which, although touched upon by Libri and laboriously investigated by Binet, had hitherto, to the best of his knowledge, remained unsolved even in the case of an equation with but one independent variable with non-constant coefficients; when the coefficients are supposed constant, the well-known solution flows as an immediate corollary from the author's general form. Essentially the method depends upon the adoption of a natural principle of notation for the given coefficients, according to which each coefficient is to be denoted by a *twofold* group of indices, the number of the double indices in a group being equal to the number of independent variables in the given equation. Thus, supposing $u_{m,n,p}\dots$ to be expressible by means of the given general equation, as a sum of u's with inferior indices, the coefficient of $u_{\mu,\nu,\pi}\dots$ in that sum must be denoted by the double index group $\begin{bmatrix} m, n, p \dots \\ \mu, \nu, \pi \dots \end{bmatrix}$. The process for obtaining the general term in $u_{x,y,z}\dots$ is then shown to be reducible virtually to the problem of effecting the simultaneous *decomposition* of the integer variables x, y, z ... into *parts* in every possible manner and order of relative arrangement, the magnitudes of such parts being limited by the degree or degrees of the given equation in respect of these variables. The collective value of the terms thus obtained constituting the complete solution may be termed, in the author's nomenclature, a hyper-cumulant, whose properties and their applications remain to be studied out as those of the elementary kinds of common cumulants have been to a considerable extent in the ordinary theory of continued fractions. The first stage in the process of constructing the terms of a general cumulant or general hyper-cumulant is almost identical with that of finding the coefficients in the expansion of a power of a polynomial function of one or several variables, differing from it indeed only in the circumstance that permutations which lead to repetitions in the latter case, represent distinct values in the former.

On Aërolites. By Professor N. S. MASKELYNE.

Professor Maskelyne prefaced a series of notices of meteorites lately added to the collection in the British Museum by some observations on the phenomena that accompany the fall of such bodies to the earth. Loud reports and the development of brilliant light in the sky are among the most generally observed of the phenomena. The fallen mass or its fragments, besides the marked characters that are constantly present, as well in composition as in the mode of aggregation of the component minerals, exhibit also invariably a superficial enamelling or incrustation. The meteorite which fell at Butsura, in India, on May 12, 1861, accompanied by successive reports and a luminosity in the sky visible in the daytime, presents some new and very interesting facts bearing on the cause of this incrustation. The whole of the fragments found, though they fell in four places, at distances of three or four miles apart, formed the parts of a large piece of an aërolite, fitting to one another with great exactness, with the exception of two of them, between which an intermediate fragment had been lost. Some of the fragments were found to be entirely coated with crust, yet capable of being adjusted to each other with unmistakeable accuracy; others again exhibited no such incrustation at the parts where they fitted to each other, and were yet, like the former, found several miles asunder. It was obvious from this that some of these fragments had become coated with crust after they had been severed, while others had been so severed without becoming subsequently incrusted.

That the incrustation was the result of superficial fusion seems the best explanation of its presence on the meteorite, as well as of the partiality with which it was distributed. Such a superficial fusion, however, could only result from the development of heat of enormous temperature very instantaneously; and the best if not he only satisfactory solution seems to be that recognized by most physicists, namely, hat it is the result of the heat generated by the aërolite entering the earth's atmosphere with the velocity of a cosmical body, and of that velocity being reduced with a suddenness that brings down the motion of the aërolite to that of a falling body in a few seconds of time. The light associated with the fall of such a body is probably due in part, as Haidinger has suggested, to the actual incandescence of the air, partly to the combustion of the iron and the ignition of the stony material as the surface of the aërolite fuses and streams away in a state of ignition and is thus left behind it in its path. The reports heard may be due to the actual bursting of the mass into fragments, from the gradual penetration towards the interior of the high temperature constantly being developed on its surface. That interior, bringing with it the intense cold of space, and the contracted volume due to that coldness (probably also brittle in consequence of it), remains in its more shrunk state, while the outer parts are expanding. Wherever there are lines of weaker aggregation therefore in the mass, or where the heat is able, from differences of conducting power in the material, to penetrate the mass unequally, a tendency in parts of the mass to break away from an inner core will ensue, and the explosion is the result. The causes that have combined to sever the mass into fragments may recur to cause explosions in the fragments, especially if their coherence has been shaken and cracks have been formed in them. If the aërolite has not lost too much of its velocity at the time of the explosions, the incrustation will recommence on the fresh surfaces. Where the velocity has been too far reduced, this process will not be repeated, and the stones will fall without a crust on the faces of fracture.

Intermediate stages of slight incrustation and even of a mere thin glazing are by no means rare, and several of these are illustrated by specimens in the British Museum.

Mr. Maskelyne next pointed out the conditions which must have been present in the earlier stages of the history of an aërolite. The presence of an excess of iron and a deficiency of oxygen is attested by the existence of metallic iron in almost every known aërolite. One has to imagine a mixture of molten metals gradually oxidizing in a rare atmosphere, and to suppose that the more oxidizable of them take precedence in their claim to the oxygen. These have, probably, during the process displaced some of the iron and nickel where these metals had become already combined, as in the cases where we find the iron isolated in the form of a microscopic, often crystallized dust in the interior of aërolitic minerals (like the suboxide of copper in avanturine glass). We have also evidence of stages in the history of the formation of an aërolite. The orbicular structure of so many of these bodies is an indication of one stage of this kind. The spherules which characterize this structure are often composed of a single crystalline and homogeneous mineral, with a radiating structure; often they are breccias made up of several crystals of the same or of different minerals united by a granular network of mineral. These spherules are often surrounded by a shell of meteoric pyrites or iron, and are set in a mixed mass, often highly porphyritic, composed of similar ingredients with the spherules. The solidification of this ground-mass marks, probably, a second stage in the history, the former indicating the very gradual separation by cooling of some of the ingredients of the aërolite, and the latter the result of the further gradual cooling of the residuary mass. There is no glass or uncrystallized matter apparent in any aërolite yet examined. Hence the meteorite, while presenting analogies with a slag in so far as that it is produced in the presence of an excess of metal, is in other respects analogous to a lava from the gradual manner in which its cooling has taken place and the different minerals have become separated out. A third stage in the history of the aërolite is exhibited in the veins of metallic iron and of other substances which are so often found not only cementing the sides of narrow fissures in meteorites, but frequently in the more compact varieties traversing with those fissures the substance of the spherules, and producing in them and the surrounding mass the phenomenon of "a heave," such as one sees in a lode when the two sides of the fissures have shifted their relative positions.

The next subject introduced was that of the minerals contained in aërolites; and Mr. Maskelyne pointed out that, from the optical characters exhibited by these minerals when under microscopic examination, he was led to believe that augite and felspar can rarely be detected in the high proportions in which they are assumed by the chemist to be present in the chondritic variety of meteorite, though constituting the mass of other kinds. In the former kind, on the other hand, the crystals seem, in the majority of cases, to exhibit the planes of polarization in directions which belong to minerals crystallizing in the prismatic system.

The following meteorites, many of which had been recently acquired by the British Museum, were next described in detail.

Chondritic Aërolites.

1. From Akbarpúr, Shahjehanpur, India, lat. 27° 48′, long. 79° 43′. An entire stone, for a long while in the British Museum, which fell at this place, April 18, 1838. It weighs 3½ lbs. Its sp. gr. = 3·73. It presents a beautifully marked surface when polished, richly veined with a dark mineral (chromite, probably).

2. The stones, some incrusted and some only partially so, the fall of which has been above alluded to, and which fell on the banks of the Gunduk, near Butsura on May 12, 1861, lat. 27° 7′, long. 84° 9′, at four places. Sp. gr. = 3·60.

3. Nellore, in Madras. A stone weighing 30 lbs., which fell at Yatoor, near this place, on January 23, 1852. Its sp. gr. = 3·63.

4. Mhow, Ghazeepúr, lat. 25° 54′, long. 83° 37′. A stone that fell on the 16th February, 1827; sp. gr. = 3·521.

5. Dhurmsala, in the Punjaub; fell July 14, 1860; sp. gr. = 3·42.

6. Kheragur (perhaps Dhenagur), near Agra; fell March 28, 1860; sp. gr. = 3·391

7. Parnallee. The largest of the two stones which fell at that village, in the Presidency of Madras, on February 28, 1857. Its weight is 130 lbs., and its sp. gr. = 3·41.

8. Durala. Fell February 18, 1815, at Durala, in the territory of the Puttealah Rajah, lat. 30° 2′, long. 76° 52′. For a long time at the East India House. It weighs 20 lbs.

9. Agra. A stone the property of William Nevill, Esq., part of the stone recorded to have fallen on August 7, 1822, at a village in the neighbourhood of Agra, 30 miles N.W. of Allahabad. Its sp. gr. = 3·666.

10, 11. Two stones that fell, the one at Umballah, at an uncertain date, in one of the years 1822 or 1823, and the other at Bitoura, 75 miles N.W. of Allahabad, on November 30, 1822; sp. gr. of Umballah stone = 3·448; of Bitoura stone = 3·57.

12. A part of one of the several stones that fell at Allahabad and Futtehpur on the last date. These last four stones may all belong to one and the same fall: but if the date of Mr. Nevill's Agra stone be correct, it is certainly a distinct one from the other three. Its high specific gravity, its large amount of iron, and general aspect would render it probable that it is so, which would confirm the correctness of its date. The Umballah stone is very unlike either of the others, and is probably a separate fall.

That from Bitoura certainly belongs to the fall of Allahabad and Futtehpur. The sp. gr. of the Allahabad stones range from 3·54 to 3·57.

13. A small stone fell in the field called the North Inch, close to Perth, in Scotland, on May 17, 1830. A small portion of it was reserved by Dr. Thomson of Glasgow, and has since passed into the possession of Mr. Nevill. The British Museum is indebted to that gentleman for the half of it. It is a remarkable little meteorite, very rich in a peculiar mineral with a radiated structure; sp. gr. = 3·491

To the class of aërolites devoid of marked spherular structure belong—

14. The Shalka stone that fell, on November 30, 1850, at Shalka in Bancoorah, Bengal.

15. That of Bustee, in Goruckpúr; lat. 26° 49′, long. 82° 44′. Perhaps the most singular of all known aërolites. It fell near that place on December 2, 1852. In it Mr. Maskelyne has detected a mineral to which he gives the name of Oldhamite—a yellow transparent body of cubic crystallization, consisting of a sulphide of calcium containing more than one equivalent of sulphur. Four other minerals in this aërolite were also crystallographically described, one of a golden-yellow colour, and cubic in its crystalline system.

16. Moradabad; sp. gr. = 3·143; fell at that place in 1808.

17. Managaon (probably Mallaigaum), lat. 20° 32′, long. 74° 30′, in Khandeish. his very remarkable stone fell on July 26, 1843. It consists of a congeries of eautiful primrose-yellow crystals entangled, as it were, in a network of an opake nineral of the same colour.

Note.—The detailed accounts of these meteorites are being published in the umbers of the 'Philosophical Magazine' for 1863.

On the Effects of different Manures on the Mixed Herbage of Grass Land.

By J. B. Lawes, *F.R.S., F.C.S., and* J. H. Gilbert, *Ph.D., F.R.S., F.C.S.*

At the Aberdeen Meeting the authors had shown the great difference in both the hemical and the botanical characters of the herbage induced by different kinds of nanure, each applied for three consecutive years on the same plot, in a portion of Ir. Lawes's park, which had been laid down as meadow probably for some enturies. Now, after the continuance of the experiment for four years more, they ave the results of a more complete botanical analysis of the produce. The full etails were exhibited in Tables, and discussed at length; but the most important f them are embodied in the Table given herewith, and the general results may be hortly stated as follows:—

1. So far as the general distribution of Graminaceous, Leguminous, and miscellaeous or weedy herbage, and the tendency to the production of leafy or stemmy roduce and to early or retarded ripening, were concerned, the characters of the roduce of the seventh season, 1862, were, in the main, similar to those before ecorded of the third season, 1858. But there was considerable change in the elative predominance of certain species on particular plots. *Dactylis glomerata*, *estuca duriuscula* or *F. pratensis*, *Avena pubescens* or *A. flavescens*, *Poa trivialis* or *. pratensis*, and *Alopecurus pratensis* had, respectively, become much more prevaent on one or more of the plots, according to the description of manure employed.

2. *Unmanured*, the mown produce consisted of 74 per cent. by weight of raminaceous, 7 per cent. Leguminous, and 19 per cent. miscellaneous or weedy erbage. It showed great variety, comprising about 40 species of plants, of which 6 were Graminaceous, 4 Leguminous, and the remainder miscellaneous, and xhibited comparatively little predominance of individual species. *Festuca duriusula*, *F. pratensis*, *Avena pubescens*, and *A. flavescens* were the most prominent; hilst the freer-growing grasses were in smaller amount, and a number of others n less proportion still. The crop was even, but very short, with little development f stem; and it was green, and comparatively late, at the time of cutting.

3. *Mixed mineral manures* (superphosphate of lime, and sulphates of potass, soda, nd magnesia) also gave about 40 species of plants; they increased the Graminaceous erbage comparatively little, and reduced the proportion in the produce both of it nd the weedy herbage, but very greatly increased both the amount per acre and he proportion of the Leguminous plants *Trifolium*, *Lathyrus*, and *Lotus*, which ogether contributed nearly one-fourth of the total produce. The description of the raminaceous herbage was not very much altered from that of the unmanured land; here was no striking predominance of individual species; but, compared with the roduce by more productive manures, there was a pretty even mixture of most of he grasses occurring without manure, and those which did show any prominence ere chiefly of the smaller and less free-growing kinds. The tendency to form tem and seed, and to early ripeness, was much greater than without manure.

4. *Ammonia salts alone* gave a produce in which 33 species only were detected; hey considerably increased both the amount per acre and the proportion in the roduce of the Graminaceous herbage, almost excluded Leguminous plants, and educed the number and amount of miscellaneous or weedy species generally, but nuch increased the luxuriance of some few, particularly the *Rumex acetosa*, *Bunium lexuosum*, and *Achillea millefolium*. The proportions were nearly 88½ per cent. raminaceous, but a fraction of 1 per cent. Leguminous, and 11½ per cent. misellaneous herbage. The relation to one another of the Graminaceous species, as o amount, was much the same as without manure, excepting that *Festuca duriusula* and *Agrostis vulgaris* were brought into much greater prominence. The in-

creased growth was characteristically that of root or base-leaves, and there was very little tendency to form stem or to ripen.

5. *Nitrate of soda alone*, like ammonia-salts alone, considerably increased the produce of Graminaceous herbage, and tended chiefly to the production of root-foliage. The nitrate, however, strikingly brought into prominence the *Alopecurus pratensis*, at the expense, compared with the produce by ammonia-salts, chiefly of *Agrostis vulgaris*, and partly of *Festuca duriuscula*. Otherwise the distribution of species was not very materially altered, the more luxuriantly-growing grasses not being much developed. The crop was much more leafy than stemmy, very dark green, and late; it contained very little Leguminous herbage, though rather more than the produce by ammonia-salts alone; and the weedy plants were luxuriant rather than numerous—*Plantago lanceolata, Centaurea nigra, Rumex acetosa, Achillea millefolium, Ranunculus*, and *Taraxacum* all being more or less encouraged.

6. The combinations of *nitrogenous-manured* (ammonia-salts or nitrates) and the *mixed mineral manure* gave by far the largest crops, the largest proportion of Graminaceous herbage, the largest proportion referable to a few species, scarcely a trace of Leguminous plants, and a small proportion, both in number and amount, of miscellaneous or weedy plants. In fact, the total number of species (particularly when ammonia-salts were used) was smaller than by any other description of manure, in one case only 21, and in another only 24, being detected; and the Graminaceous herbage in several cases amounted to 90 per cent. or more of the total crop. The produce was very luxuriant, with a good development of stem and stem-leaves, and a much greater tendency to ripen than when the ammonia-salts or nitrates were used without the mineral manure. The predominating grasses were the most bulky and free-growing ones, *Dactylis glomerata* and *Poa trivialis* being very prominent, and *Avena pubescens* or *A. flavescens, Agrostis vulgaris, Lolium perenne*, and *Holcus lanatus* somewhat so. *Festuca duriuscula, F. pratensis, Arrhenatherum avenaceum, Alopecurus pratensis, Bromus mollis*, and others, were almost excluded.

7. *Farmyard manure* considerably increased the growth of the grasses and of some few weeds, particularly *Rumex, Ranunculus, Bunium*, and *Achillea*, and reduced that of clover and other Leguminous plants, more especially when used in combination with ammonia-salts. It greatly encouraged the growth of the good grass *Poa trivialis*, and of the bad one *Bromus mollis*, and, when in conjunction with ammonia-salts, the *Dactylis glomerata*. Under both conditions, *Festuca duriuscula* and *F. pratensis* were nearly excluded, and *Avena flavescens, A. pubescens, Agrostis vulgaris, Lolium perenne*, and *Arrhenatherum avenaceum* were very much reduced. The crops were upon the whole bulky, comparatively simple as to description of herbage (not more than 28 species in all being detected), fairly luxuriant both in stem and leaf, somewhat rough and coarse, and showed a tendency to unequal ripeness.

8. *Graminaceous herbage* was only encouraged when nitrogenous manures were employed; and when these were used alone, the produce was very leafy, and generally (according to the amounts applied) the crop was very dark green and showed comparatively little tendency to ripen; but when the nitrogenous manures were used in conjunction with mineral manures, the Graminaceous produce was very much more luxuriant, very much more stemmy, showed much more tendency to ripen, and almost excluded other descriptions of herbage.

9. *Leguminous herbage* was almost entirely excluded whenever nitrogenous manures were used in any quantity, whether in the form of ammonia-salts or nitrates, alone or in combination with mineral manures, but somewhat less so with nitrates than with ammonia-salts. Mineral manures alone, containing both potash and phosphoric acid, greatly increased the growth of Leguminous plants, particularly the perennial red clover and meadow vetchling. Farmyard manure, like artificial nitrogenous manures, also, but in a less degree, much diminished the proportion of the Leguminous herbage.

10. *Miscellaneous or weedy herbage* was diminished in the number of species and in the frequency of occurrence, by every description of manure, but by exclusively mineral manures less so than by any others. Nitrogenous manures, especially in combination with mineral constituents, diminished the number and frequency

OF SS LAND.

RB SEVENTH SEASON, 1862. [*To face page* 192.

perphosphate of Lime.						FARMYARD MANURE.		COMMON NAMES.
monia Salts Nitrogen) heat-straw.		With Ammonia Salts (=164 lbs. Nitrogen).	With Ammonia Salts (=164 lbs. Nitrogen) & Sawdust.	With Nitrate of Soda.		Alone.	With Ammonia Salts (=41 lbs. Nitrogen).	
				(=41 lbs. Nitrogen.)	(=82 lbs. Nitrogen.)			
b	Mean	13 a	13 b	14	15	16	17	
4		15	14	15	13	13	16	

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very strikingly, but at the same time greatly increased the luxuriance of a few species, especially *Rumex acetosa*, and frequently *Bunium flexuosum* and *Achillea millefolium*. *Plantago* and *Ranunculus* were generally discouraged by active manures, excepting farmyard manure and nitrate of soda. The nitrate also favoured *Centaurea nigra* and *Taraxacum dens-leonis*.

11. Considerable increase of produce was only obtained by means of farmyard manure, or artificial manures containing both mineral constituents and ammonia-salts or nitrates. The crops so obtained were much more Graminaceous, and consisted in much greater proportion of but a few species of plants. The grasses developed were chiefly of the more bulky and freer-growing kinds, and the produce was generally very stemmy—the more so, and the coarser, the more excessive the manuring.

12. Meadow-land mown for hay should not be manured exclusively with artificial manures, but should receive a dressing of well-rotted farmyard manure every four or five years.

13. Sewage-irrigation, like active manures applied to meadow-land in the ordinary way, has also a tendency to develope chiefly the Graminaceous herbage, excluding the Leguminous, and to a great extent the miscellaneous or weedy plants. It also, at the expense of the rest, encourages a few free-growing grasses, among which, according to the locality and other circumstances, *Poa trivialis*, *Triticum repens*, *Dactylis glomerata*, *Holcus lanatus*, and *Lolium perenne* have been observed to be very prominent. The result is an almost exclusively Graminaceous and very simple herbage. But as the produce of sewage-irrigated meadows is generally cut or fed off in a young and succulent condition, the tendency which the great luxuriance of a few very free-growing grasses has to give a coarse and stemmy later growth is less objectionable than in the case of meadows left for hay.

On the Past and Present Expenses and Social Condition of University Education. By the Rev. W. Emery, *B.D., Senior Fellow and Tutor of Corpus Christi College, Cambridge, late Senior Proctor of the University.*

He traced the history from the earliest times, when Joffrid the Abbot of Croyland sent Gilbert and other three monks to Cottenham, who gave instruction in a barn in Cambridge. It was not till A.D. 1257 that St. Peter's, the first college in the University, was founded, when the expense of a student ranged up to £2 a year. The students then lived hard lives, being contented with a penny-piece of beef amongst four, accompanied by salt and oatmeal only, and were obliged to run up and down, "being without fire, in order to get a heat on their feet before going to bed." The author then gave a very interesting and humorous account of the provision for students in 1645, as stated by Strype in letters to his mother, written from Jesus College. In 1763 expenses increased, tutorial charges increased, and the system of private tutors was introduced. Fifty years since it might be gathered, from the large number of noblemen and fellow-commoners in the University, that expenses had reached a much higher point, while, about thirty years back, extravagance, immorality, and idleness had attained their utmost height. Since that time a great improvement had taken place, and now there was a much better system of habits, and a larger and more regular attendance on professional and college lectures. The estimates for the expenses of students at present for three terms a year were on three scales—the lowest being about £120, the second £180, and the highest £250. If private tutors were engaged, a sum of £8 or £10 a term must be added, and to those who resided in college in the long vacations an additional expense of £15 or £20 was incurred. Some men of great economy lived in the University for £100 a year. These rates included all University charges and private expenses as derived from the tradesmen's bills sent in to the tutors. Some of the sizars had lived on such low sums as £45 and £39 per annum. In most of the colleges the students might obtain assistance from scholarships, the lowest stipend attached to which would provide an undergraduate with a private tutor. It had been shown by evidence that one of the sources of extravagance in undergraduates was the habits acquired by them at public schools, and it was reasonable to suppose that a young man who had expended from £200 to £300 a year at Eton or Harrow would not spend less at Cambridge. A student might, however, pass creditably through his course for £150 a year. The paper then dwelt on the social advantages derived from membership and the welding together of classes in the University, and stated that there was no town of equal extent and population that was more quiet after half-past nine at night than Cambridge, while rioting and dissipation were of limited extent, the larger number of students being economical and well-conducted.

LIST OF PLATES.

PLATE I.

Illustrative of Mr. Fleeming Jenkin's paper on Thermo-electric Currents in Circuits of one Metal.

PLATE II.

Illustrative of Mr. G. J. Symons's paper on the Fall of Rain in the British Isles during the Years 1860 and 1861.

PLATE III.

Illustrative of the Fourth Report of the Committee on Steamship Performance.

APPENDIX III.

List of Papers of which Abstracts have not been received.

◆

On Electrical Tensions. By LATIMER CLARK.

On the Storms of the St. Lawrence and Great Lakes of Canada.
By Dr. HURLBURT.

On some Facts relating to two brilliant Auroras in Canada.
By Dr. HURLBURT.

On some Principles to be considered in Mineralogical Classification.
By T. STERRY HUNT, *M.A., F.R.S.*

On the nature of Nitrogen, and the Theory of Nitrification.
By T. STERRY HUNT, *M.A., F.R.S.*

On some of the Difficulties arising in the practice of Photography, and the means of removing them. By MAXWELL LYTE, *M.A., F.C.S.*

On Ossiferous Caves in Malta. By Dr. FALCONER, *F.R.S.*

On the Alluvial Deposits of the Rhine. By R. A. C. GODWIN-AUSTEN, *F.R.S.*

On the Origin and Mode of occurrence of the Petroleum of North America.
By T. STERRY HUNT, *M.A., F.R.S.*

On the Structure and Origin of certain Limestones and Dolomites.
By T. STERRY HUNT, *M.A., F.R.S.*

On the Diluvial and Alluvial Deposits of Central Germany.
By Dr. K. VON SEEBACH.

On the asserted Plurality of Species of existing Asiatic Elephants.
By Dr. FALCONER, *F.R.S.*

Remarks on all the known forms of Human Entozoa.
By T. SPENCER COBBOLD, *M.D., F.L.S.*

A Tabular View of the relation which subsists between the Three Kingdoms of Nature with regard to Organization. By H. FREKE, *M.B.*

On the Termination of Motor Nerves, and their connexion with muscular contractions. By Prof. W. KÖHNE.

Ascent of the Cameroon Mountains. By Captain R. BURTON.

An Account of the Veddahs of Ceylon. By JOHN BAILEY.

On Vancouver's Island. By Commander MAYNE.

On the Geography of Bread Plants. By M. Michelsen.

Cambodia and the Laos States. By M. Henri Mouhot.

Late Explorations in Australia by Burke, Wills, &c. By Sir C. Nicholson.

Ascent of Um Shaumur, in the Peninsula of Sinai. By Rev. G. Prout.

The Middle Island of New Zealand. By John Rochfort.

On the Yang-tze-Kiang River, China. By Colonel Sarel.

On the Proceedings of the United University Mission to Africa.
By Rev. H. C. Scudamore.

On a Voyage on the Lake Nyassa, Eastern Africa. By Rev. Mr. Stewart.

On the Eastern Archipelago and New Guinea. By Alfred R. Wallace.

On the Economic Effects of recent Gold Discoveries. By H. Fawcett, M.A.

Some Statistics of Zostera marina as a substitute for Cotton. By H. Harben.

The Tariffs and Trade of various Countries during the last Ten Years.
By R. Valpy.

On the Practicability of a Division of the Employer's Profits amongst the Workpeople. By Dr. Watts.

On Machinery for Composing and Distributing Type.
By Charles Hart. (Communicated by P. Le Neve Foster, M.A.)

On an improved form of "Link" Motion. By J. Nasmyth.

On an improved Printing Telegraph Apparatus. By M. Sortais.

On a proposed new arrangement of Ships' Rudders.
By Captain J. Steuart, *R.N.*

On the Practice and Principles of Diverting Rivers and Stoppage of the Breaches in Embankments. By C. Vignoles.

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Contents:—Prof. Daubeny, on the Present State of our Knowledge with respect to Mineral and Thermal Waters;—Major E. Sabine, on the Direction and Intensity of the Terrestrial Magnetic Force in Scotland;—J. Richardson, on North American Zoology;—Rev. J. Challis on the Mathematical Theory of Fluids;—J. T. Mackay, a Comparative View of the more remarkable Plants which characterize the neighbourhood of Dublin and Edinburgh, and the South-west of Scotland, &c.;—J. T. Mackay, Comparative Geographical Notices of the more remarkable Plants which characterize Scotland and Ireland;—Report of the London Sub-Committee of the Medical Section on the Motions and Sounds of the Heart;—Second Report of the Dublin Sub-Committee on the Motions and Sounds of the Heart;—Report of the Dublin Committee on the Pathology of the Brain and Nervous System;—J. W. Lubbock, Account of the Recent Discussions of Observations of the Tides;—Rev. B. Powell, on determining the Refractive Indices for the Standard Rays of the Solar Spectrum in various media;—Dr. Hodgkin, on the Communication between the Arteries and Absorbents;—Prof. Phillips, Report of Experiments on Subterranean Temperature;—Prof. Hamilton, on the Validity of a Method recently proposed by G. B. Jerrard, for Transforming and Resolving Equations of Elevated Degrees.

Together with the Transactions of the Sections, Prof. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTH MEETING, at Liverpool, 1837, *Published at* 16*s.* 6*d.*

Contents:—Major E. Sabine, on the Variations of the Magnetic Intensity observed at different points of the Earth's Surface;—Rev. W. Taylor, on the various modes of Printing for the Use of the Blind;—J. W. Lubbock, on the Discussions of Observations of the Tides;—Prof. T. Thomson, on the Difference between the Composition of Cast Iron produced by the Cold and Hot Blast;—Rev. T. R. Robinson, on the Determination of the Constant of Nutation by the Greenwich Observations;—R. W. Fox, Experiments on the Electricity of Metallic Veins, and the Temperature of Mines;—Provisional Report of the Committee of the Medical Section of the British Association, appointed to investigate the Composition of Secretions, and the Organs producing them;—Dr. G. O. Rees, Report from the Committee for inquiring into the Analysis of the Glands, &c. of the Human Body;—Second Report of the London Sub-Committee of the British Association Medical Section, on the Motions and Sounds of the Heart;—Prof. Johnston, on the Present State of our Knowledge in regard to Dimorphous Bodies;—Lt.-Col. Sykes, on the Statistics of the Four Collectorates of Dukhun, under the British Government;—E. Hodgkinson, on the relative Strength and other Mechanical Properties of Iron obtained from the Hot and Cold Blast;—W. Fairbairn, on the Strength and other Properties of Iron obtained from the Hot and Cold Blast;—Sir J. Robison, and J. S. Russell, Report of the Committee on Waves;—Note by Major Sabine, being an Appendix to his Report on the Variations of the Magnetic Intensity observed at different Points of the Earth's Surface;—J. Yates, on the Growth of Plants under Glass, and without any free communication with the outward Air, on the Plan of Mr. N. J. Ward, of London.

Together with the Transactions of the Sections, Prof. Traill's Address and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTH MEETING, at Newcastle, 1838, *Published at* 15*s.*

CONTENTS:—Rev. W. Whewell, Account of a Level Line, measured from the Bristol Channel to the English Channel, by Mr. Bunt;—Report on the Discussions of Tides, prepared under the direction of the Rev. W. Whewell;—W. S. Harris, Account of the Progress and State of the Meteorological Observations at Plymouth;—Major E. Sabine, on the Magnetic Isoclinal and Isodynamic Lines in the British Islands;—D. Lardner, LL.D., on the Determination of the Mean Numerical Values of Railway Constants;—R. Mallet, First Report upon Experiments upon the Action of Sea and River Water upon Cast and Wrought Iron;—R. Mallet, on the Action of a Heat of 212° Fahr., when long continued, on Inorganic and Organic Substances.

Together with the Transactions of the Sections, Mr. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINTH MEETING, at Birmingham, 1839, *Published at* 13*s.* 6*d.*

CONTENTS:—Rev. B. Powell, Report on the Present State of our Knowledge of Refractive Indices, for the Standard Rays of the Solar Spectrum in different media;—Report on the Application of the Sum assigned for Tide Calculations to Rev. W. Whewell, in a Letter from T. G. Bunt, Esq.;—H. L. Pattinson, on some Galvanic Experiments to determine the Existence or Non-Existence of Electrical Currents among Stratified Rocks, particularly those of the Mountain Limestone formation, constituting the Lead Measures of Alton Moor;—Sir D. Brewster, Reports respecting the two series of Hourly Meteorological Observations kept in Scotland;—Report on the subject of a series of Resolutions adopted by the British Association at their Meeting in August 1838, at Newcastle;—R. Owen, Report on British Fossil Reptiles;—E. Forbes, Report on the Distribution of Pulmoniferous Mollusca in the British Isles;—W. S. Harris, Third Report on the Progress of the Hourly Meteorological Register at Plymouth Dockyard.

Together with the Transactions of the Sections, Rev. W. Vernon Harcourt's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TENTH MEETING, at Glasgow, 1840, *Published at* 15*s.*

CONTENTS:—Rev. B. Powell, Report on the recent Progress of discovery relative to Radiant Heat, supplementary to a former Report on the same subject inserted in the first volume of the Reports of the British Association for the Advancement of Science;—J. D. Forbes, Supplementary Report on Meteorology;—W. S. Harris, Report on Prof. Whewell's Anemometer, now in operation at Plymouth;—Report on "The Motion and Sounds of the Heart," by the London Committee of the British Association, for 1839–40;—Prof. Schönbein, an Account of Researches in Electro-Chemistry;—R. Mallet, Second Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at various temperatures, upon Cast Iron, Wrought Iron and Steel;—R. W. Fox, Report on some Observations on Subterranean Temperature;—A. F. Osler, Report on the Observations recorded during the years 1837, 1838, 1839, and 1840, by the Self-registering Anemometer erected at the Philosophical Institution, Birmingham;—Sir D. Brewster, Report respecting the two Series of Hourly Meteorological Observations kept at Inverness and Kingussie, from Nov. 1st, 1838 to Nov. 1st, 1839;—W. Thompson, Report on the Fauna of Ireland: Div. *Vertebrata*;—C. J. B. Williams, M.D., Report of Experiments on the Physiology of the Lungs and Air-Tubes;—Rev. J. S. Henslow, Report of the Committee on the Preservation of Animal and Vegetable Substances.

Together with the Transactions of the Sections, Mr. Murchison and Major E. Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE ELEVENTH MEETING, at Plymouth, 1841, *Published at* 13*s.* 6*d.*

CONTENTS:—Rev. P. Kelland, on the Present state of our Theoretical and Experimental Knowledge of the Laws of Conduction of Heat;—G. L. Roupell, M.D., Report on Poisons;—T. G. Bunt, Report on Discussions of Bristol Tides, under the direction of the Rev. W. Whewell;—D. Ross, Report on the Discussions of Leith Tide Observations, under the direction of the Rev. W. Whewell;—W. S. Harris, upon the working of Whewell's Anemometer at Plymouth during the past year;—Report of a Committee appointed for the purpose of superintending the scientific cooperation of the British Association in the System of Simultaneous Observations in Terrestrial Magnetism and Meteorology;—Reports of Committees appointed to provide Meteorological Instruments for the use of M. Agassiz and Mr. M'Cord;—Report of a Committee to superintend the reduction of Meteorological Observations;—Report of a Committee for revising the Nomenclature of the Stars;—Report of a Committee for obtaining Instruments and Registers to record Shocks and Earthquakes in Scotland and Ireland;—Report of a Committee on the Preservation of Vegetative Powers in Seeds;—Dr. Hodgkin, on Inquiries into the Races of Man;—Report of the Committee appointed to report how far the Desiderata in our knowledge of the Condition of the Upper Strata of the Atmosphere may be supplied by means of Ascents in Balloons or otherwise, to ascertain the probable expense of such Experiments, and to draw up Directions for Observers in such circumstances;—R. Owen, Report on British Fossil Reptiles;—Reports on the Determination of the Mean Value of Railway Constants;—D. Lardner, LL.D., Second and concluding Report on the Determination of the Mean Value of Railway Constants;—E. Woods, Report on Railway Constants;—Report of a Committee on the Construction of a Constant Indicator for Steam-Engines.

Together with the Transactions of the Sections, Prof. Whewell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWELFTH MEETING, at Manchester 1842, *Published at* 10*s.* 6*d.*

CONTENTS:—Report of the Committee appointed to conduct the cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—J. Richardson, M.D., Report on the present State of the Ichthyology of New Zealand;—W. S. Harris, Report on the Progress of Meteorological Observations at Plymouth;—Second Report of a Committee appointed to make Experiments on the Growth and Vitality of Seeds;—C. Vignoles, Report of the Committee on Railway Sections;—Report of the Committee for the Preservation of Animal and Vegetable Substances;—Lyon Playfair, M.D., Abstract of Prof. Liebig's Report on Organic Chemistry applied to Physiology and Pathology;—R. Owen, Report on the British Fossil Mammalia, Part I.;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—L. Agassiz, Report on the Fossil Fishes of the Devonian System or Old Red Sandstone;—W. Fairbairn, Appendix to a Report on the Strength and other Properties of Cast Iron obtained from the Hot and Cold Blast;—D. Milne, Report of the Committee for Registering Shocks of Earthquakes in Great Britain;—Report of a Committee on the construction of a Constant Indicator for Steam-Engines, and for the determination of the Velocity of the Piston of the Self-acting Engine at different periods of the Stroke;—J. S. Russell, Report of a Committee on the Form of Ships;—Report of a Committee appointed "to consider of the Rules by which the Nomenclature of Zoology may be established on a uniform and permanent basis;"—Report of a Committee on the Vital Statistics of large Towns in Scotland;—Provisional Reports, and Notices of Progress in special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Lord Francis Egerton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTEENTH MEETING, at Cork, 1843, *Published at* 12*s.*

CONTENTS:—Robert Mallet, Third Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at Various Temperatures, upon Cast Iron, Wrought Iron and Steel;—Report of the Committee appointed to conduct the cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Sir J. F. W. Herschel, Bart., Report of the Committee appointed for the Reduction of Meteorological Observations;—Report of the Committee appointed for Experiments on Steam-Engines;—Report of the Committee appointed to continue their Experiments on the Vitality of Seeds;—J. S. Russell, Report of a Series of Observations on the Tides of the Frith of Forth and the East Coast of Scotland;—J. S. Russell, Notice of a Report of the Committee on the Form of Ships;—J. Blake, Report on the Physiological Action of Medicines;—Report of the Committee on Zoological Nomenclature;—Report of the Committee for Registering the Shocks of Earthquakes, and making such Meteorological Observations as may appear to them desirable;—Report of the Committee for conducting Experiments with Captive Balloons;—Prof. Wheatstone, Appendix to the Report;—Report of the Committee for the Translation and Publication of Foreign Scientific Memoirs;—C. W. Peach on the Habits of the Marine Testacea;—E. Forbes, Report on the Mollusca and Radiata of the Ægean Sea, and on their distribution, considered as bearing on Geology;—L. Agassiz, Synoptical Table of British Fossil Fishes, arranged in the order of the Geological Formations;—R. Owen, Report on the British Fossil Mammalia, Part II.;—E. W. Binney, Report on the excavation made at the junction of the Lower New Red Sandstone with the Coal Measures at Collyhurst;—W.

Thompson, Report on the Fauna of Ireland: Div. *Invertebrata*;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Earl of Rosse's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FOURTEENTH MEETING, at York, 1844, *Published at* £1.

CONTENTS:—W. B. Carpenter, on the Microscopic Structure of Shells;—J. Alder and A. Hancock, Report on the British Nudibranchiate Mollusca;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—Report of a Committee appointed by the British Association in 1840, for revising the Nomenclature of the Stars;—Lt.-Col. Sabine, on the Meteorology of Toronto in Canada;—J. Blackwall, Report on some recent researches into the Structure, Functions, and Œconomy of the *Araneidea*, made in Great Britain;—Earl of Rosse, on the Construction of large Reflecting Telescopes;—Rev. W. V. Harcourt, Report on a Gas-furnace for Experiments on Vitrifaction and other Applications of High Heat in the Laboratory;—Report of the Committee for Registering Earthquake Shocks in Scotland;—Report of a Committee for Experiments on Steam-Engines;—Report of the Committee to investigate the Varieties of the Human Race;—Fourth Report of a Committee appointed to continue their Experiments on the Vitality of Seeds;—W. Fairbairn, on the Consumption of Fuel and the Prevention of Smoke;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—Sixth Report of the Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Prof. Forchhammer on the influence of Fucoidal Plants upon the Formations of the Earth, on Metamorphism in general, and particularly the Metamorphosis of the Scandinavian Alum Slate;—H. E. Strickland, Report on the recent Progress and Present State of Ornithology;—T. Oldham, Report of Committee appointed to conduct Observations on Subterranean Temperature in Ireland;—Prof. Owen, Report on the Extinct Mammals of Australia, with descriptions of certain Fossils indicative of the former existence in that continent of large Marsupial Representatives of the Order Pachydermata;—W. S. Harris, Report on the working of Whewell and Osler's Anemometers at Plymouth, for the years 1841, 1842, 1843;—W. R. Birt, Report on Atmospheric Waves;—L. Agassiz, Rapport sur les Poissons Fossiles de l'Argile de Londres, with translation;—J. S. Russell, Report on Waves;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Dean of Ely's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTEENTH MEETING, at Cambridge, 1845, *Published at* 12*s*.

CONTENTS:—Seventh Report of a Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Lt.-Col. Sabine, on some points in the Meteorology of Bombay;—J. Blake, Report on the Physiological Actions of Medicines;—Dr. Von Boguslawski, on the Comet of 1843;—R. Hunt, Report on the Actinograph;—Prof. Schönbein, on Ozone;—Prof. Erman, on the Influence of Friction upon Thermo-Electricity;—Baron Senftenberg, on the Self-Registering Meteorological Instruments employed in the Observatory at Senftenberg;—W. R. Birt, Second Report on Atmospheric Waves;—G. R. Porter, on the Progress and Present Extent of Savings' Banks in the United Kingdom;—Prof. Bunsen and Dr. Playfair, Report on the Gases evolved from Iron Furnaces, with reference to the Theory of Smelting of Iron;—Dr. Richardson, Report on the Ichthyology of the Seas of China and Japan;—Report of the Committee on the Registration of Periodical Phenomena of Animals and Vegetables;—Fifth Report of the Committee on the Vitality of Seeds;—Appendix, &c.

Together with the Transactions of the Sections, Sir J. F. W. Herschel's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTEENTH MEETING, at Southampton, 1846, *Published at* 15*s*.

CONTENTS:—G. G. Stokes, Report on Recent Researches in Hydrodynamics;—Sixth Report of the Committee on the Vitality of Seeds;—Dr. Schunck on the Colouring Matters of Madder;—J. Blake, on the Physiological Action of Medicines;—R. Hunt, Report on the Actinograph;—R. Hunt, Notices on the Influence of Light on the Growth of Plants;—R. L. Ellis, on the Recent Progress of Analysis;—Prof. Forchhammer, on Comparative Analytical

Researches on Sea Water;—A. Erman, on the Calculation of the Gaussian Constants for 1829;—G. R. Porter, on the Progress, present Amount, and probable future Condition of the Iron Manufacture in Great Britain;—W. R. Birt, Third Report on Atmospheric Waves;—Prof. Owen, Report on the Archetype and Homologies of the Vertebrate Skeleton;—J. Phillips, on Anemometry;—J. Percy, M.D., Report on the Crystalline Flags;—Addenda to Mr. Birt's Report on Atmospheric Waves.

Together with the Transactions of the Sections, Sir R. I. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTEENTH MEETING, at Oxford, 1847, *Published at 18s.*

Contents:—Prof. Langberg, on the Specific Gravity of Sulphuric Acid at different degrees of dilution, and on the relation which exists between the Development of Heat and the coincident contraction of Volume in Sulphuric Acid when mixed with Water;—R. Hunt, Researches on the Influence of the Solar Rays on the Growth of Plants;—R. Mallet, on the Facts of Earthquake Phenomena;—Prof. Nilsson, on the Primitive Inhabitants of Scandinavia;—W. Hopkins, Report on the Geological Theories of Elevation and Earthquakes;—Dr. W. B. Carpenter, Report on the Microscopic Structure of Shells;—Rev. W. Whewell and Sir James C. Ross, Report upon the Recommendation of an Expedition for the purpose of completing our knowledge of the Tides;—Dr. Schunck, on Colouring Matters;—Seventh Report of the Committee on the Vitality of Seeds;—J. Glynn, on the Turbine or Horizontal Water-Wheel of France and Germany;—Dr. R. G. Latham, on the present state and recent progress of Ethnographical Philology;—Dr. J. C. Prichard, on the various methods of Research which contribute to the Advancement of Ethnology, and of the relations of that Science to other branches of Knowledge;—Dr. C. C. J. Bunsen, on the results of the recent Egyptian researches in reference to Asiatic and African Ethnology, and the Classification of Languages;—Dr. C. Meyer, on the Importance of the Study of the Celtic Language as exhibited by the Modern Celtic Dialects still extant;—Dr. Max Müller, on the Relation of the Bengali to the Arian and Aboriginal Languages of India;—W. R. Birt, Fourth Report on Atmospheric Waves;—Prof. W. H. Dove, Temperature Tables, with Introductory Remarks by Lieut.-Col. E. Sabine;—A. Erman and H. Petersen, Third Report on the Calculation of the Gaussian Constants for 1829.

Together with the Transactions of the Sections, Sir Robert Harry Inglis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTEENTH MEETING, at Swansea, 1848, *Published at 9s.*

Contents:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—J. Glynn on Water-pressure Engines;—R. A. Smith, on the Air and Water of Towns;—Eighth Report of Committee on the Growth and Vitality of Seeds;—W. R. Birt, Fifth Report on Atmospheric Waves;—E. Schunck, on Colouring Matters;—J. P. Budd, on the advantageous use made of the gaseous escape from the Blast Furnaces at the Ystalyfera Iron Works;—R. Hunt, Report of progress in the investigation of the Action of Carbonic Acid on the Growth of Plants allied to those of the Coal Formations;—Prof. H. W. Dove, Supplement to the Temperature Tables printed in the Report of the British Association for 1847;—Remarks by Prof. Dove on his recently constructed Maps of the Monthly Isothermal Lines of the Globe, and on some of the principal Conclusions in regard to Climatology deducible from them; with an introductory Notice by Lt.-Col. E. Sabine;—Dr. Daubeny, on the progress of the investigation on the Influence of Carbonic Acid on the Growth of Ferns;—J. Phillips, Notice of further progress in Anemometrical Researches;—Mr. Mallet's Letter to the Assistant-General Secretary;—A. Erman, Second Report on the Gaussian Constants;—Report of a Committee relative to the expediency of recommending the continuance of the Toronto Magnetical and Meteorological Observatory until December 1850.

Together with the Transactions of the Sections, the Marquis of Northampton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINETEENTH MEETING, at Birmingham, 1849, *Published at 10s.*

Contents:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—Earl of Rosse, Notice of Nebulæ lately observed in the Six-feet Reflector;—Prof. Daubeny, on the Influence of Carbonic Acid Gas on the health of Plants, especially of those allied to the Fossil Remains found in the Coal Formation;—Dr. Andrews, Report on the Heat of Combination;—Report of the Committee on the Registration of the Periodic Phenomena of Plants and

Animals;—Ninth Report of Committee on Experiments on the Growth and Vitality of Seeds;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from Aug. 9, 1848 to Sept. 12, 1849;—R. Mallet, Report on the Experimental Inquiry on Railway Bar Corrosion;—W. R. Birt, Report on the Discussion of the Electrical Observations at Kew.

Together with the Transactions of the Sections, the Rev. T. R. Robinson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTIETH MEETING, at Edinburgh, 1850, *Published at 15s.*

CONTENTS:—R. Mallet, First Report on the Facts of Earthquake Phenomena;—Rev. Prof. Powell, on Observations of Luminous Meteors;—Dr. T. Williams, on the Structure and History of the British Annelida;—T. C. Hunt, Results of Meteorological Observations taken at St. Michael's from the 1st of January, 1840, to the 31st of December, 1849;—R. Hunt, on the present State of our Knowledge of the Chemical Action of the Solar Radiations;—Tenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Major-Gen. Briggs, Report on the Aboriginal Tribes of India;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—E. Forbes, Report on the Investigation of British Marine Zoology by means of the Dredge;—R. MacAndrew, Notes on the Distribution and Range in depth of Mollusca and other Marine Animals, observed on the coasts of Spain, Portugal, Barbary, Malta, and Southern Italy in 1849;—Prof. Allman, on the Present State of our Knowledge of the Freshwater Polyzoa;—Registration of the Periodical Phenomena of Plants and Animals;—Suggestions to Astronomers for the Observation of the Total Eclipse of the Sun on July 28, 1851.

Together with the Transactions of the Sections, Sir David Brewster's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIRST MEETING, at Ipswich, 1851, *Published at 16s. 6d.*

CONTENTS:—Rev. Prof. Powell, on Observations of Luminous Meteors;—Eleventh Report of Committee on Experiments on the Growth and Vitality of Seeds;—Dr. J. Drew, on the Climate of Southampton;—Dr. R. A. Smith, on the Air and Water of Towns: Action of Porous Strata, Water and Organic Matter;—Report of the Committee appointed to consider the probable Effects in an Œconomical and Physical Point of View of the Destruction of Tropical Forests;—A. Henfrey, on the Reproduction and supposed Existence of Sexual Organs in the Higher Cryptogamous Plants;—Dr. Daubeny, on the Nomenclature of Organic Compounds;—Rev. Dr. Donaldson, on two unsolved Problems in Indo-German Philology;—Dr. T. Williams, Report on the British Annelida;—R. Mallet, Second Report on the Facts of Earthquake Phenomena;—Letter from Prof. Henry to Col. Sabine, on the System of Meteorological Observations proposed to be established in the United States;—Col. Sabine, Report on the Kew Magnetographs;—J. Welsh, Report on the Performance of his three Magnetographs during the Experimental Trial at the Kew Observatory;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from September 12, 1850, to July 31, 1851;—Ordnance Survey of Scotland.

Together with the Transactions of the Sections, Prof. Airy's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SECOND MEETING, at Belfast, 1852, *Published at 15s.*

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena;—Twelfth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1851–52;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants;—A Manual of Ethnological Inquiry;—Col. Sykes, Mean Temperature of the Day, and Monthly Fall of Rain at 127 Stations under the Bengal Presidency;—Prof. J. D. Forbes, on Experiments on the Laws of the Conduction of Heat;—R. Hunt, on the Chemical Action of the Solar Radiations;—Dr. Hodges, on the Composition and Œconomy of the Flax Plant;—W. Thompson, on the Freshwater Fishes of Ulster;—W. Thompson, Supplementary Report on the Fauna of Ireland;—W. Wills, on the Meteorology of Birmingham;—J. Thomson, on the Vortex-Water-Wheel;—J. B. Lawes and Dr. Gilbert, on the Composition of Foods in relation to Respiration and the Feeding of Animals.

Together with the Transactions of the Sections, Colonel Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-THIRD MEETING, at Hull, 1853, *Published at* 10*s*. 6*d*.

CONTENTS:—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1852-53;—James Oldham, on the Physical Features of the Humber;—James Oldham, on the Rise, Progress, and Present Position of Steam Navigation in Hull;—William Fairbairn, Experimental Researches to determine the Strength of Locomotive Boilers, and the causes which lead to Explosion;—J. J. Sylvester, Provisional Report on the Theory of Determinants;—Professor Hodges, M.D., Report on the Gases evolved in Steeping Flax, and on the Composition and Œconomy of the Flax Plant;—Thirteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Robert Hunt, on the Chemical Action of the Solar Radiations;—John P. Bell, M.D., Observations on the Character and Measurements of Degradation of the Yorkshire Coast; First Report of Committee on the Physical Character of the Moon's Surface, as compared with that of the Earth;—R. Mallet, Provisional Report on Earthquake Wave-Transits; and on Seismometrical Instruments;—William Fairbairn, on the Mechanical Properties of Metals as derived from repeated Meltings, exhibiting the maximum point of strength and the causes of deterioration;—Robert Mallet, Third Report on the Facts of Earthquake Phenomena (continued).

Together with the Transactions of the Sections, Mr. Hopkins's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FOURTH MEETING, at Liverpool, 1854, *Published at* 18*s*.

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena (continued);—Major-General Chesney, on the Construction and General Use of Efficient Life-Boats;—Rev. Prof. Powell, Third Report on the present State of our Knowledge of Radiant Heat;—Colonel Sabine, on some of the results obtained at the British Colonial Magnetic Observatories;—Colonel Portlock, Report of the Committee on Earthquakes, with their proceedings respecting Seismometers;—Dr. Gladstone, on the influence of the Solar Radiations on the Vital Powers of Plants, Part 2;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1853-54;—Second Report of the Committee on the Physical Character of the Moon's Surface;—W. G. Armstrong, on the Application of Water-Pressure Machinery;—J. B. Lawes and Dr. Gilbert, on the Equivalency of Starch and Sugar in Food;—Archibald Smith, on the Deviations of the Compass in Wooden and Iron Ships;—Fourteenth Report of Committee on Experiments on the Growth and Vitality of Seeds.

Together with the Transactions of the Sections, the Earl of Harrowby's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIFTH MEETING, at Glasgow, 1855, *Published at* 15*s*.

CONTENTS:—T. Dobson, Report on the Relation between Explosions in Coal-Mines and Revolving Storms;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants growing under different Atmospheric Conditions, Part 3;—C. Spence Bate, on the British Edriophthalma;—J. F. Bateman, on the present state of our knowledge on the Supply of Water to Towns;—Fifteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1854-55;—Report of Committee appointed to inquire into the best means of ascertaining those properties of Metals and effects of various modes of treating them which are of importance to the durability and efficiency of Artillery;—Rev. Prof. Henslow, Report on Typical Objects in Natural History;—A. Follett Osler, Account of the Self-Registering Anemometer and Rain-Gauge at the Liverpool Observatory;—Provisional Reports.

Together with the Transactions of the Sections, the Duke of Argyll's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SIXTH MEETING, at Cheltenham, 1856, *Published at* 18*s*.

CONTENTS;—Report from the Committee appointed to investigate and report upon the effects produced upon the Channels of the Mersey by the alterations which within the last fifty years have been made in its Banks;—J. Thomson, Interim Report on progress in Researches on the Measurement of Water by Weir Boards;—Dredging Report, Frith of Clyde, 1856;—Rev. B. Powell, Report on Observations of Luminous Meteors, 1855–1856;—Prof. Bunsen and Dr. H. E. Roscoe, Photochemical Researches;—Rev. James Booth, on the Trignometry of the Parabola, and the Geometrical Origin of Logarithms;—R. MacAndrew, Report on the Marine Testaceous Mollusca of the North-east Atlantic and Neighbouring Seas, and the physical conditions affecting their development;—P. P. Carpenter, Report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America;—T. C. Eyton, Abstract of First Report on the Oyster Beds and Oysters of the British Shores; —Prof. Phillips, Report on Cleavage and Foliation in Rocks, and on the Theoretical Explanations of these Phenomena: Part I.;—Dr. T. Wright on the Stratigraphical Distribution of the Oolitic Echinodermata;—W. Fairbairn, on the Tensile Strength of Wrought Iron at various Temperatures;—C. Atherton, on Mercantile Steam Transport Economy;—J. S. Bowerbank, on the Vital Powers of the Spongiadæ;—Report of a Committee upon the Experiments conducted at Stormontfield, near Perth, for the artificial propagation of Salmon;—Provisional Report on the Measurement of Ships for Tonnage;—On Typical Forms of Minerals, Plants and Animals for Museums;—J. Thomson, Interim Report on Progress in Researches on the Measurement of Water by Weir Boards;—R. Mallet, on Observations with the Seismometer;—A. Cayley, on the Progress of Theoretical Dynamics;—Report of a Committee appointed to consider the formation of a Catalogue of Philosophical Memoirs.

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PROCEEDINGS OF THE TWENTY-SEVENTH MEETING, at Dublin, 1857, *Published at 15s.*

CONTENTS:—A. Cayley, Report on the Recent Progress of Theoretical Dynamics;—Sixteenth and final Report of Committee on Experiments on the Growth and Vitality of Seeds; —James Oldham, C.E., continuation of Report on Steam Navigation at Hull;—Report of a Committee on the Defects of the present methods of Measuring and Registering the Tonnage of Shipping, as also of Marine Engine-Power, and to frame more perfect rules, in order that a correct and uniform principle may be adopted to estimate the Actual Carrying Capabilities and Working-Power of Steam Ships;—Robert Were Fox, Report on the Temperature of some Deep Mines in Cornwall;—Dr. G. Plarr, De quelques Transformations de la Somme $\Sigma_0^{-\alpha} t \frac{a^{t|+1}\beta^{t|+1}\delta^{t|+1}}{1^{t|+1}\gamma^{t|+1}\epsilon^{t|+1}}$, a étant entier négatif, et de quelques cas dans lesquels cette somme est exprimable par une combinaison de factorielles, la notation $a^{t|+1}$ désignant le produit des t facteurs $a\,(a+1)\,(a+2)$ &c....$(a+t-1)$;—G. Dickie, M.D., Report on the Marine Zoology of Strangford Lough, County Down, and corresponding part of the Irish Channel;—Charles Atherton, Suggestions for Statistical Inquiry into the extent to which Mercantile Steam Transport Economy is affected by the Constructive Type of Shipping, as respects the Proportions of Length, Breadth, and Depth;—J. S. Bowerbank, Further Report on the Vitality of the Spongiadæ;—John P. Hodges, M.D., on Flax;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Rev. Baden Powell, Report on Observations of Luminous Meteors, 1856–57;—C. Vignoles, C.E., on the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;—Professor W. A. Miller, M.D., on Electro-Chemistry; —John Simpson, R.N., Results of Thermometrical Observations made at the 'Plover's' Wintering-place, Point Barrow, latitude 71° 21′ N., long. 156° 17′ W., in 1852–54;—Charles James Hargrave, LL.D., on the Algebraic Couple; and on the Equivalents of Indeterminate Expressions;—Thomas Grubb, Report on the Improvement of Telescope and Equatorial Mountings;—Professor James Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College at Cirencester;—William Fairbairn on the Resistance of Tubes to Collapse;—George C. Hyndman, Report of the Proceedings of the Belfast Dredging Committee;—Peter W. Barlow, on the Mechanical Effect of combining Girders and Suspension Chains, and a Comparison of the Weight of Metal in Ordinary and Suspension Girders, to produce equal deflections with a given load;—J. Park Harrison, M.A., Evidences of Lunar Influence on Temperature;—Report on the Animal and Vegetable Products imported into Liverpool from the year 1851 to 1855 (inclusive);—Andrew Henderson, Report on the Statistics of Life-boats and Fishing-boats on the Coasts of the United Kingdom.

Together with the Transactions of the Sections, Rev. H. Lloyd's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-EIGHTH MEETING, at Leeds, September 1858, *Published at 20s.*

CONTENTS:—R. Mallet, Fourth Report upon the Facts and Theory of Earthquake Phenomena;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1857–58;—R. H. Meade, on some Points in the Anatomy of the Araneidea or true Spiders, especially on the internal structure of their Spinning Organs;—W. Fairbairn, Report of the Committee on the Patent Laws;—S. Eddy, on the Lead Mining Districts of Yorkshire;—W. Fairbairn, on the Collapse of Glass Globes and Cylinders;—Dr. E. Perceval Wright and Prof. J. Reay Greene, Report on the Marine Fauna of the South and West Coasts of Ireland;—Prof. J. Thomson, on Experiments on the Measurement of Water by Triangular Notches in Weir Boards;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Michael Connal and William Keddie, Report on Animal, Vegetable, and Mineral Substances imported from Foreign Countries into the Clyde (including the Ports of Glasgow, Greenock, and Port Glasgow) in the years 1853, 1854, 1855, 1856, and 1857;—Report of the Committee on Shipping Statistics;—Rev. H. Lloyd, D.D., Notice of the Instruments employed in the Magnetic Survey of Ireland, with some of the Results;—Prof. J. R. Kinahan, Report of Dublin Dredging Committee, appointed 1857–58;—Prof. J. R. Kinahan, Report on Crustacea of Dublin District;—Andrew Henderson, on River Steamers, their Form, Construction, and Fittings, with reference to the necessity for improving the present means of Shallow-Water Navigation on the Rivers of British India;—George C. Hyndman, Report of the Belfast Dredging Committee;—Appendix to Mr. Vignoles' paper "On the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;"—Report of the Joint Committee of the Royal Society and the British Association, for procuring a continuance of the Magnetic and Meteorological Observatories;—R. Beckley, Description of a Self-recording Anemometer.

Together with the Transactions of the Sections, Prof. Owen's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-NINTH MEETING, at Aberdeen, September 1859, *Published at 15s.*

CONTENTS:—George C. Foster, Preliminary Report on the Recent Progress and Present State of Organic Chemistry;—Professor Buckman, Report on the Growth of Plants in the Garden of the Royal Agricultural College, Cirencester;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops;—A. Thomson, Esq. of Banchory, Report on the Aberdeen Industrial Feeding Schools;—On the Upper Silurians of Lesmahago, Lanarkshire;—Alphonse Gages, Report on the Results obtained by the Mechanico-Chemical Examination of Rocks and Minerals;—William Fairbairn, Experiments to determine the Efficiency of Continuous and Self-acting Breaks for Railway Trains;—Professor J. R. Kinahan, Report of Dublin Bay Dredging Committee for 1858–59;—Rev. Baden Powell, Report on Observations of Luminous Meteors for 1858–59;—Professor Owen, Report on a Series of Skulls of various Tribes of Mankind inhabiting Nepal, collected, and presented to the British Museum, by Bryan H. Hodgson, Esq., late Resident in Nepal, &c. &c.;—Messrs. Maskelyne, Hadow, Hardwich, and Llewelyn, Report on the Present State of our Knowledge regarding the Photographic Image;—G. C. Hyndman, Report of the Belfast Dredging Committee for 1859;—James Oldham, Continuation of Report of the Progress of Steam Navigation at Hull;—Charles Atherton, Mercantile Steam Transport Economy as affected by the Consumption of Coals;—Warren de la Rue, Report on the present state of Celestial Photography in England;—Professor Owen, on the Orders of Fossil and Recent Reptilia, and their Distribution in Time;—Balfour Stewart, on some Results of the Magnetic Survey of Scotland in the years 1857 and 1858, undertaken, at the request of the British Association, by the late John Welsh, Esq., F.R.S.;—W. Fairbairn, The Patent Laws: Report of Committee on the Patent Laws;—J. Park Harrison, Lunar Influence on the Temperature of the Air;—Balfour Stewart, an Account of the Construction of the Self-recording Magnetographs at present in operation at the Kew Observatory of the British Association;—Prof. H. J. Stephen Smith, Report on the Theory of Numbers, Part I.;—Report of the Committee on Steam-ship performance;—Report of the Proceedings of the Balloon Committee of the British Association appointed at the Meeting at Leeds;—Prof. William K. Sullivan, Preliminary Report on the Solubility of Salts at Temperatures above 100° Cent., and on the Mutual Action of Salts in Solution.

Together with the Transactions of the Sections, Prince Albert's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTIETH MEETING, at Oxford, June and July 1860, *Published at 15s.*

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors, 1859–60;—J. R. Kinahan, Report of Dublin Bay Dredging Committee;—Rev. J. Anderson, Report on the Excavations in Dura Den;—Professor Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College, Cirencester;—Rev. R. Walker, Report of he Committee on Balloon Ascents;—Prof. W. Thomson, Report of Committee appointed to repare a Self-recording Atmospheric Electrometer for Kew, and Portable Apparatus for observing Atmospheric Electricity;—William Fairbairn, Experiments to determine the Effect of Vibratory Action and long-continued Changes of Load upon Wrought-iron Girders;—R. P. Greg, Catalogue of Meteorites and Fireballs, from A.D. 2 to A.D. 1860;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part II.;—Vice-Admiral Moorsom, on the Performance of Steam-vessels, the Functions of the Screw, and the Relations of its Diameter and Pitch to the Form of the Vessel;—Rev. W. V. Harcourt, Report on the Effects of long-continued Heat, illustrative of Geological Phenomena;—Second Report of the Committee on Steam-ship Performance;—Interim Report on the Gauging of Water by Triangular Notches;—List of the British Marine Invertebrate Fauna.

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PROCEEDINGS OF THE THIRTY-FIRST MEETING, at Manchester, September 1861, *Published at* £1.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors;—Dr. E. Smith, Report on the Action of Prison Diet and Discipline on the Bodily Functions of Prisoners, Part I.;—Charles Atherton, on Freight as affected by Differences in the Dynamic Properties of Steamships;—Warren De la Rue, Report on the Progress of Celestial Photography since the Aberdeen Meeting;—B. Stewart, on the Theory of Exchanges, and its recent extension;—Drs. E. Schunck, R. Angus Smith, and H. E. Roscoe, on the Recent Progress and Present Condition of Manufacturing Chemistry in the South Lancashire District;—Dr. J. Hunt, on Ethno-Climatology; or, the Acclimatization of Man;—Prof. J. Thomson, on Experiments on the Gauging of Water by Triangular Notches;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops;—Prof. H. Hennessy, Provisional Report on the Present State of our Knowledge respecting the Transmission of Sound-signals during Fogs at Sea;—Dr. P. L. Sclater and F. von Hochstetter, Report on the Present State of our Knowledge of the Birds of the Genus *Apteryx* living in New Zealand;—J. G. Jeffreys, Report of the Results of Deep-sea Dredging in Zetland, with a Notice of several Species of Mollusca new to Science or to the British Isles;—Prof. J. Phillips, Contributions to a Report on the Physical Aspect of the Moon;—W. R. Birt, Contribution to a Report on the Physical Aspect of the Moon;—Dr. Collingwood and Mr. Byerley, Preliminary Report of the Dredging Committe of the Mersey and Dee;—Third Report of the Committee on Steamship Performance;—J. G. Jeffreys, Preliminary Report on the Best Mode of preventing the Ravages of *Teredo* and other Animals in our Ships and Harbours;—R. Mallet, Report on the Experiments made at Holyhead to ascertain the Transit-Velocity of Waves, analogous to Earthquake Waves, through the local Rock Formations;—T. Dobson, on the Explosions in British Coal-Mines during the year 1859;—J. Oldham, Continuation of Report on Steam Navigation at Hull;—Professor G. Dickie, Brief Summary of a Report on the Flora of the North of Ireland;—Professor Owen, on the Psychical and Physical Characters of the Mincopies, or Natives of the Andaman Islands, and on the Relations thereby indicated to other Races of Mankind;—Colonel Sykes, Report of the Balloon Committee;—Major-General Sabine, Report on the Repetition of the Magnetic Survey of England;—Interim Report of the Committee for Dredging on the North and East Coasts of Scotland;—W. Fairbairn, on the Resistance of Iron Plates to Statical Pressure and the Force of Impact by Projectiles at High Velocities;—W. Fairbairn, Continuation of Report to determine the effect of Vibratory Action and long-continued Changes of Load upon Wrought-Iron Girders;—Report of the Committee on the Law of Patents;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part III.

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